EXPLORATION PLAN FOR KAHAUALE'A

SUBMITTED TO

THE BOARD OF LAND AND NATURAL RESOURCES

STATE OF HAWAII

BY

THE ESTATE OF JAMES CAMPBELL

AND

TRUE/MID-PACIFIC GEOTHERMAL VENTURE

TABLE OF CONTENTS

EXPLORATION PLAN FOR KAHAUALE'A

LIST OF FIGURES

EXPLORATION PLAN FOR KAHAUALE'A

EXPLORATION PLAN FOR KAHAUALE'A

1.0 EXECUTIVE SUMMARY

This Exploration Plan for Kahauale'a outlines the planned activities for the drilling and testing of up to 8 geothermal wells within the Permitted Exploration Area. Besides the meteorological station currently operating in Fern Forest Subdivision, an air quality monitoring survey is in progress in the communities surrounding Kahauale'a. Ambient levels of SO2, H2S, radon, mercury, total suspended particulates, and water quality are being measured to establish pre-drilling baselines. Following the Exploration Plan, several other Plans required by the D&O of February 25, 1983, will be submitted prior to the start of field operations.

Because of pending appeals to the D&O, a precise schedule cannot be specified at this time, but once these impediments are resolved, a rig will be brought over from the Mainland and drilling of KA-1 should begin within 4 months. The first well will require 2-1/2 months to complete, followed by a testing period. Additional drill sites are planned to the north, east, and northeast of KA-1.

Information about the geothermal resource at Kahauale'a can be derived from the various on-site studies and drilling results from the Lower East Rift. In order to economically justify a prospect, there must be a reasonable assurance that a resource will be discovered. This assurance was derived from a study of Holcomb's Kilauea East Rift Geology Maps, an aeromagnetic survey, data from a microearthquake study, and experience in the Lower East Rift. The geological studies show that the planned drilling activity in Kahauale'a is within the East Rift Zone and therefore should encounter a sizeable heat source. Surface cracks and fissures are further assurance that a dike system occurs in the area. The aeromagnetic survey shows that the rocks beneath Kahauale'a are non-magnetic signifying rocks above Curie Temperature or greater than 500 degrees C, suggesting a long lasting resource. Over a two month period, microearthquake data was collected in Kahauale'a. The results show that about 1500 events occurred, which is evidence that the reservoir rocks could be highly fractured, a condition necessary for a commercial resource.

The presence of a large heat resource in the East Rift, the favorable microearthquake results, suggesting fracturing, and a hydrological system that provides dike impounded water, together constitues strongly favorable evidence of the presence of geothermal resources.

Extensive geophysical measurements were conducted along the Lower East Rift Zone as part of the Hawaii Geothermal Project from 1973 to 1975. When these geophysical results are combined with the information from the five existing geothermal wells, the data shows that all geophysical studies except aeromagnetic and microearthquake were not useful and offered misleading results. Resistivity and SP anomalies, commonly used to identify prospective areas, produced both successful and unsuccessful wells. Magnetic and gravity surveys offered only the location of the Rift Zone which may be inferred from surface geology. Interpretation of ground noise data led to the recommendation of a location where a dry hole was subsequently drilled. Five temperature gradient holes, which are used to determine areas of substantial heat flow, were available. Surveys in these wells showed that meaningful data was not obtained until depths reached below sea level. At Kahauale'a, however, where the elevation is 2500 feet, a large size hole and appropriate large size drilling rig would have to be mobilized to successfully drill that deep. Without an access road, this is not practical. A large size hole introduces a convection cell in the hole which distorts the actual temperature of the rocks, thus defeating the purpose of the temperature gradient holes.

Based on a review and analysis of the geophysical studies and the results of drilling in the Lower East Rift, the Developer believes that all the appropriate surface measurements that can be done to increase the chances of drilling a successful well at Kahauale'a have been done. The hydrological and reservoir models developed from the information indicates that a liquid dominated geothermal reservoir will be encountered at 6000 to 8000 feet below sea level with presssures of 2200 to 2800 psig and temperatures of 600 degrees F. Because of its structural position, gases and water salinities are expected to be lower than HGP-A.

Since drilling a geothermal well is the ultimate test and the most expensive test to conduct, it would only be done if all reasonable geological and geophysical surveys had been conducted and the results indicated a potential geothermal resource. Such is the case with Kahauale'a. Although further surveys could be made, this would be a waste of money for the results would have the same defects (mainly that the depth of investigation is too shallow) as experienced during the Hawaii Geothermal Project.

The initial well will be drilled 4000 feet east and 16,750 feet south of the northeast corner of Kahauale'a, approximately 1000 feet east of the lcoation specified in the Project EIS. Following drilling, this well will be tested extensively to determine resevoir and fluid characteristics. The location of additional wells to be drilled and tested will depend on the results of the prior wells.

A management team has been in place for some time to carry out this project. A field organization to supervise and conduct day to day drilling operations has been developed.

The primary route selected in the Project EIS from the Volcano Highway through the Shipman Estate, around the highest density of adenophorous periens, and on to the Permitted Area remains the optimum route.

In order to maintain a safe and orderly operation, the Developer has a complete program planned to handle security, communications, well blowout prevention, emergency well shut-in procedures, medical evacuation and lava flows.

Modern blowout prevention equipment with blind and pipe rams and bag type preventers will be used during the drilling. The drilling program has also been designed to use adequate mud weights to prevent hazardous fluid entries. If a situation occurs where the rig has to shut-down because of an impending lava flow, the well will be left with a "bridge plug" or "storm plug" to safely isolate the well and enable an expeditious clearing of personnel from the well site. These plugs are designed to withstand high pressures and temperatures and are commonly used in an area where quick shut-down due to huuricanes or high seas is necessary.

Medical services in case of personnel injury beyond on-site first aid will be by ambulance to Keaau, the closest hospital. For burns, personnel will be evacuated to Honolulu (Straub Clinic) or a recognized burn center such as Sherman Oaks, California.

The current eruptive activity along the East Rift has caused lava flows to enter Kahauale'a and cover approximately 1/2 of the Permitted Area. However, because no wells have been drilled and the KA-1 site has not been affected, there is no impact on the planned drilling program. The current eruptive activity will be monitored and drillsites selected in areas that will be the least likely to be affected by lava flows.

2.0 INTRODUCTION

2.1 REFERENCE. The Estate of James Campbell applied to the Board of Land and Natural Resources(BLNR), State of Hawaii, for a Conservation District Use Application(No. HA-3/2/82-1463) in order to obtain approval to develop geothermal energy resources located in Kahauale'a, Puna District, County of Hawaii. Pursuant to the Application, a Decision and Order(D&O) was issued by the BLNR on February 25, 1983. Paragraph 9.2.2 of the D&O requires an Exploration Plan to be submitted prior to the start of field operations.

2.2 NON-WAIVER. It must be kept in mind that Applicant is appealing the BLNR's failure to grant Development in the latter's D&O. Consequently, Applicant is submitting the Exploration Plan for the purpose of preventing a technical breech of the D&O and to demonstrate Applicant's continuing good faith during the time it takes to resolve impediments, but this submission does not constitute a waiver of any of Applicant's rights or powers.

2.3 CONTENT. This Exploration Plan for Kahauale'a presents a complete review of the activities necessary to comply with the BLNR's D&O permitting Applicant to carry out a geothermal resource exploration program in the East Rift Zone of Kilauea Volcano upon certain conditions. Included is a detailed discussion of the nature of the resource and the methodology that was used to ascertain that a commercial resource is likely to be discovered. Direct evidence from five(5) deep geothermal wells located in the Lower East Rift Zone was gathered, analyzed, and applied to Kahauale'a. Considerations in drill site selection, procedures to accomplish the well drilling and testing, and the planned sequence of drilling are set forth in this document. An estimated schedule of activities and a staffing plan are provided. This schedule is based on certain assumptions concerning administration of permits from regulatory agencies and resolution of contingencies. Mitigation measures for possible environmental impacts associated with the field operations are described. Finally, the Plan contains specific steps that are planned to ensure the safety of personnel and natural environment.

It is the intent of this document to address all of the items requested in the D&O concerning the Exploration Plan and demonstrate the skill and professionalism of the Developer(True/Mid-Pacific Geothermal Venture) to develop geothermal energy and make it a major part of Hawaii's economic base.

3.0 RESOURCE CHARACTERISTICS

3.1 GENERAL. Kahauale'a is located in the Puna District, County of Hawaii. The property is situated on the slopes of Kilauea Volcano, east of the summit caldera. A significant geologic feature called the East Rift Zone passes through the middle of Kahauale'a(See Figure 1). Five deep geothermal wells have been drilled along this feature in search of a commercial geothermal reservoir. Preliminary evidence indicates that three of the five wells encountered a commercial resource.

Kilauea Volcano is one the most active volcanoes in the world. It has been built up largely by eruptions along its two rift zones, the Southwest Rift Zone and the East Rift Zone(Stearns and McDonald, 1946). Magma enters a storage chamber beneath the summit, then a majority of the magma either erupts into the caldera or enters the rift zones through a system of subsurface conduits. Most of the magma appears on the surface as lava flows, but some of the magma forms dikes within fissures and remains beneath the rift zones as a source of geothermal heat.

The East Rift Zone, identified by a series of spatter cones, pit craters, and fissures, extends from the summit caldera southeast for about five miles, then turns northeastward and stretches to Cape Kumakahi at a heading of north 65 degrees east. The width of the East Rift Zone ranges from about 3 miles wide in the upper rift to about 2 miles wide in the lower rift, somewhat wider than originally thought (Holcomb, 1980).

Stearns and McDonald described the general subsurface stratigraphy and structure of Kilauea. Volcanological studies establish that eruptions occur frequently along the East Rift Zone and are expected to continue. Hence the earth's natural heat energy is made available here at relatively shallow depths. If this heat can be transferred to a fluid such as water, then the ingredients exist to form a hydrothermal system that can be developed as a primary fuel source for the generation of electricity.

Because of extremely high rainfalls over the entire windward side of the Big Island, abundant water is available to supply underground aquifers essential to the formation of a geothermal reservoir. In the Kilauea/Mauna Loa complex, rainwater percolates through the porous and permeable surface lavas until an impermeable barrier such as volcanic ash or dike system is reached. Then water flows downslope to the east and then northeast toward Hilo as the East Rift Zone is encountered. With such huge amounts of water(1 billion gallons per day according to Stearns and McDonald), some of the water migrates into the Rift Zone. In the Rift Zone, diking causes the water to be held up and impounded, while the magma intrusions heat the water creating convection cells. Figure 2 is an idealized hydrothermal model. When the water flashes to steam, mineral deposits form in the pore spaces and fractures of the lava rocks. Eventually the deposits(mainly calcium carbonate) cause the lava to become essentially impermeable. This impermeable layer serves as a cap rock so that flashing no longer occurs beneath it, and a hot water or liquid dominated geothermal reservoir is formed. Because lavas are brittle, they are prone to fracturing when subjected to stresses from magma movement and tectonic events. Toward the makai side of the Rift Zone, a similar phenomenom occurs, only this time sea water is substituted for fresh rain water. Since there is 500 times more salt in sea water than in rain water, the mineralization of pore spaces is accelerated and is more complete. In fact, given sufficient time, the entire resevoir may be plugged with mineralization caused by circulation of hot sea water. This could partly explain why wells drilled along the south portion of the East Rift have heat but no permeability.

This has been a general description of the geothermal system beneath the East Rift. Obviously the actual system is more complex. Information from all the wells drilled must be studied in order to fully understand the geothermal system in the East Rift. Evidence to suggest the existence of a geothermal system beneath Kahauale'a is set forth in the next section.

3.2 KAHAUALE'A RESOURCE DESCRIPTION. The area of interest for geothermal resource development is called Kahauale'a. This property is owned in fee by the Estate of James Campbell. A complete metes and bounds description of the property is included in Appendix A. Kahauale'a covers 25,461 acres(21,943 acres in Conservation District), but only a small portion will be affected by geothermal development as shown in Figure 3. The figure also shows the 880 acres permitted for initial exploration and the location of the initial well.

As mentioned earlier, Holcomb's 1980 study of the Kilauea East Rift contains the most authoritative geologic information. A detailed description of every surface expression along the East Rift of Kilauea is shown on two maps. One of the objectives of his study was to better define the northern and southern boundaries of the East Rift Zone. An outline of Kahauale'a and the permitted exploration area is shown on a section taken from Holcomb's maps(Figure 4). Clearly the permitted area contains numerous cracks and fissures, characteristic of the Rift Zone. In fact Holcomb goes into great detail to corroborate his interpretation of the Rift Zone Boundary near Kahauale'a on pages 183 to 188 in his report. Self potential(SP) data through the area shows an anomaly that corresponds with the northernmost crack shown on Figure 4.The SP anomaly is significant because it could be interpreted to define a boundary where water either enters or is diverted by the dikes in the Rift Zone. Thus the area planned for drilling is definitely within the East Rift Zone.

Being in the Rift Zone implies that heat is available from the magma intrusions that never reach the surface. Additional evidence in the form of an aeromagnetic survey confirms the presence of rocks heated to temperatures greater than 500 degrees C. An aeromagnetic survey of the Big Island was conducted by the USGS in 1978(Godson, et al., 1981). The essence of an aeromagnetic survey is to measure changes in the magnetic character in the earth's crust. Rocks in solid form usually show some magnetism. However, rocks heated above their Curie Point (usually greater than 500 degrees C) are non-magnetic. The aeromagnetic survey, Figure 5, shows the non-magnetic (negative gammas) character of the Kilauea and Mauna Loa summit areas where molten lava is known to exist. The East Rift shows non-magnetic character near the summit and then progressively gains magnetism as distance from the summit increases.

The permitted exploration area in Kahauale'a is marked on the aeromagnetic survey. It shows a generally non-magnetic character suggesting that the rocks beneath are heated to temperatures in excess of 500 degrees C. This is positive evidence that the heat source is available which is an essential ingredient for a geothermal system.

As part of the exploration program carried out by the True/Mid-Pacific Geothermal Venture, a microearthquake survey in Kahauale'a was conducted in January, February, and March 1982. This geophysical tool was considered to be one of more definitive tools used in the Hawaii Geothermal Project. In concept, small seismic events are triggered by stress cracking when rocks cool. Also earthquakes might occur when magma intrudes into a fissure system and induces fracturing. Since fracturing is extremely important in developing permeability in a geothermal reservoir, an area with frequent earthquake activity suggests favorable reservoir characteristics. This correlation has been demonstrated most dramatically in The Geysers Field, where microearthquakes almost exactly correlate with the steam producing area(Figure 6).

Over the study period, twelve seismometers located in Kahauale'a monitored more than 1500 individual events. Figure 7 shows the estimated locations of approximately 100 events within or near Kahauale'a that could be located with reasonable accuracy. The majority of these events were shallower than 2 km which places them in the expected depth range of the geothermal reservoir. Inspection of the earthquake locations shows two concentrations: one west of Kamoamoa and the second, between Kalalua and Puu Kahauale'a. About 1400 additional earthquakes were recorded, but only at one or two stations and thus they could not be located. Nevertheless, they provide additional evidence of an abundance of small very local earthquakes. Figure 8 shows the total number of events, both locatable and unlocatable, recorded during the period from February 7 through 13,1982. Results of the survey are encouraging because of the large number of earthquakes recorded in the areas planned for drilling. This would suggest frequent movement is occurring in the subsurface and such movement could induce fractures to be created or enlarged in a geothermal reservoir. It may also be concluded that because of the widespread occurrence of microearthquakes over the entire Kahauale'a East Rift, that a large area may be potentially productive.

There is a theoretical method to convert earthquake activity to rock strength called Poisson's Ratio. The higher Poisson's Ratio is, the lower the strength of the rock and the more likely it is to be fractured. Although this measure is very qualitative, experience from the Lower East Rift shows that it is not very useful in arriving at meaningful conclusions.

The data shows that Kahauale'a and the permitted area are within the East Rift Zone of Kilauea and thus should have a good source of heat. Aeromagnetic surveys confirm the presence of heat by indicating non-magnetic (very hot) material throughout the permitted area. The hydrologic model of the East Rift Zone suggests that adequate supplies of water are available. The existence of many microearthquakes indicates that a fractured reservoir is likely to be encountered. Finally, five deep geothermal wells have been drilled in the same geologic province (East Rift) as the planned Kahauale'a well. Since three of the five wells appear to be commercial, there is a 60% chance that Kahauale'a (KA-1) will encounter a commercial resource. This is much larger than the 11.3% chance of success that historical evidence shows to be the case for geothermal exploration(Edmiston, 1982). This direct evidence was used to support the current plan to drill a deep exploration well.

Extensive studies were done from 1973 to 1975 in the Lower East Rift Zone as part of the Hawaii Geothermal Project. The next section will discuss these studies and show that the exploration studies conducted at Kahauale'a were prudent and effective in satisfying the Developer that a geothermal resource is likely to be encountered. Additional studies were considered and could have been conducted, but based on the Lower East Rift Zone experience, little reliance could be placed on any results from these studies.

3.3 GEOTHERMAL ACTIVITY IN THE LOWER EAST RIFT. For two years from May 1973 to May 1975, a group of scientists from the Hawaii Institute of Geophysics (HIG) studied the entire Big Island to determine the nature of geothermal resources. They quickly focused on the Kilauea East Rift as the best location for a geothermal resource. Furthermore the Lower Part of the East Rift, a triangular area bounded by the Pahoa-Kaimu road, the Pahoa to Cape Kumakahi Road, and the ocean, was studied in detail mainly due to the accessibility of the area.

Geological and geophysical surveys common to geothermal exploration were conducted. Surveys included:

Photogeologic

Geoelectric (SP, resistivity, ground noise)

Magnetic and Gravity

Passive seismic(microearthquake)

Geochemical

Hydrology

In 1976, a deep geothermal test well called HGP-A was drilled to a depth of 6435 feet in the Lower East Rift Zone(See Figure 9). The well encounterd hot water with temperatures as high as 676 degrees F and also produced enough energy to justify installation of a 3MW power plant. In 1980, encouraged by the success of HGP-A, Geothermal Energy Development Company (GEDCO) drilled a well called Ashida 1 two-and-a-half miles to the southwest of HGP-A to a depth of about 8000 feet. Temperatures above 390 degrees F, suitable for a geothermal resource, were measured in the well, and the well produced some measurable, but small, quantity of geothermal fluids. Other information is being held in confidence. GEDCO drilled a second well in 1981 about 2500 feet south of HGP-A. Complete information about this well is not available, however, it is commonly believed that the well, called Lani Puna 1, was drilled to a depth of about 8350 feet and the results were identical to the Ashida 1 well, good temperature but non-commercial producing rates. Immediately following this well, Thermal Power Company, operating for the Puna Geothermal Venture(PGV), drilled two wells, Kapoho State 1 and 2 about 1700 feet north of HGP-A. Kapoho State 1 was drilled to 7290 feet and apparently encountered temperatures above 390 degrees F and produced geothermal fluids. Kapoho State 2 was drilled to a depth of 8005 feet and also apparently encountered a geothermal resource.

Based on the qualitative drilling results of four privately financed wells, the published mechanical condition of the wells, and detailed information from HGP-A, a model of the geothermal reservoir can be constructed. Figure 10, shows a NW-SE cross-section drawn perpendicular to the East Rift axis. All five completed wells are projected onto the cross-section. When a well is drilled into the East Rift, temperature gradients remain relatively low (4-5 degrees per 100 feet) until a certain depth is reached. Then the gradients increase markedly to 10-30 degrees per 100 feet. One of the key decisions that is made during drilling is the setting depth of the 9-5/8" casing string. This must be set prior to entering a producing zone or mechanical problems with the well such as poor cementing will occur. Thus a correlation can be made on the assumption that the 9-5/8" casing is run when temperature gradients start to increase indicating that the reservoir is close at hand. Records of the HGP-A well indicate that the 9-5/8" casing was set at a rather shallow depth not corresponding to the gradient change occurred in HGP-A at a depth of 3000 feet.

By contouring the setting depth of the 9-5/8 " casing in four wells with the depth of gradient change in HGP-A, a rather smooth curve establishes the depth where the gradient change occurs across the Rift Zone. This surface could also be called the top of the cap rock. The next marker that can be developed corresponds to the top of the reservoir or the bottom of the cap rock. In HGP-A, a section 800 feet thick was essentially isothermal indicating a convection cell. This convection cell was set up because of a fractured zone where fluids can circulate freely. Since the GEDCO wells had little permeability, there should be only a thin convection zone nearby. On the other hand, the PGV wells were successful and should have a convection zone similar in thickness to HGP-A. Thus the main geothermal reservoir starts at a uniform thickness and then gradually gets thinner from northwest to southeast.

At the bottom of HGP-A, the temperature surveys indicate the start of another conduction zone with temperatures of 625 degrees F. This isotherm probably marks the bottom of the reservoir.

The cross section also shows a pressure profile which is based on data from HGP-A. Pressure gradients of .296 psi/foot are much lower than a normal hydrostatic gradient of .433 psi/foot. This is because the water is heated to around 600 degrees F. Published data show that the density of water will be reduced by 68% when heated from 60 degrees to 600 degrees F.

It is postulated that the Rift Zone displays similar characteristics along its axis. If KA-1 is projected down rift onto this cross-section using sea level as a datum, the reservoir markers can be extended to estimate the character of the geothermal resource at Kahauale'a. This shows that the main convection zone will occur at depths of 6000-8000 feet below sea level, and reservoir pressures are projected to be 2200 to 2800 psig. A liquid dominated reservoir is expected, and because of the structural position, the resource should be less saline and contain less H_2S than HGP-A.

Now that a reservoir model has been developed and the results of the five wells have been discussed, it is interesting to compare predictions based on the early geophysical studies with actual outcomes in the Lower East Rift.

Holcomb's studies were not published until 1980. When the wells located in the Lower East Rift are overlaid onto Holcomb's geologic maps(Figure 11),two observations can be made. First no cracks or fissures are located south of both GEDCO wells. That raises a question as to whether those wells were actually drilled in the Rift Zone. It also correlates well with the reservoir model since little or no diking appears to be available to block out the sea water. Second there are well defined surface cracks and fissures within a hundred feet of the HGP-A and PGV wells. Thus the presence of surface cracks seems to have some bearing on the success of wells.

As mentioned earlier, aeromagnetic data qualitatively delineates hot areas based on whether or not the subsurface rocks are magnetic or non-magnetic. On Figure 5 is shown the same aeromagnetic survey discussed in Section 2.2. In the Lower East Rift, the three commercial wells are located in areas with the same or lower magnetic intensity than the two GEDCO wells. This means that the rocks are hotter under the three good wells. The data further indicate that hotter rocks underlie Kahauale'a compared to the Lower Rift areas in which wells were drilled. This does not necessarily mean that hotter temperatures will be encountered in Kahauale'a, but it does indicate that the heat source under Kahauale'a could be hotter than the heat source under HGP-A. Hotter temperatures could be interpreted to mean that the geothermal resource at Kahauale'a could last longer.

One of the most commonly used geophysical surveys in geothermal exploration is the electrical resistivity survey: the theory being that rocks saturated with water are less resistive than dry rocks. Also hot rocks are less resistive than cold rocks. At least three different types of surveys were conducted in the Lower Rift. These were dipole-bipole, DC, and time domain electromagnetic (TDEM). Probably the most definitive survey was the dipole-bipole by Zablocki in 1974. This survey identified five resistivity lows called anomalies, in the Lower Rift. These anomalies are shown in Figure 12. One of the five is considered erroneous by the author, because of cultural interference. In any case when the five completed wells are located on the resistivity maps, it shows that all the wells were drilled in the vicinity of or on resistivity anomalies. Yet two of the five did not encounter geothermal fluids. In fact the Ashida 1 well was drilled near what was predicted to be the most favorable anomaly. The misleading results can probably be attributed to inexperience and shallow depth of investigation. Because the subsurface is a layered system with a highly resistive surface layer and a highly conductive layer at 700 meters, interpretation of the raw data is very difficult. It appears that the anomalies were reflecting shallow features and not the reservoirs at 4000-6000 feet. It is true that the successful wells were drilled on resistivity anomalies, but so were the dry holes. Therefore resistivity itself is misleading and could lead to drilling in the wrong spot.

The other electrical studies showed basically the same type of confusing results. In fact, the good wells were drilled on the apparent high resistivity anomaly located by the TDEM survey.

Another very basic geothermal exploration tool is the temperature gradient hole. The idea is to identify subsurface hot spots by drilling small diameter shallow holes to measure the temperature gradients at several locations. When this was done in wells of the Lower East Rift, it was found that meaningful temperature gradients did not even appear until sea level was reached. Since most gradient holes are about 500 feet deep, this technique would not be practical at Kahauale'a which is located at 2500 feet above sea level. In addition, a gradient hole should be of small diameter to avoid heat convection from occurring within the wellbore and distorting the actual temperature gradients. A deep gradient hole would necessitate a large diameter borehole and thus defeats the purpose of a temperature gradient survey.

In the Lower East Rift, three temperature gradient holes were drilled. Data from two of these holes when combined with water well data show the obvious, that high temperatures occur in the Rift Zone. The well by well data shown in Figure 13 demonstrates that the data is not useful because two of the wells displayed a temperature reversal that rendered the data unuseable. The well with the highest gradient of 25 degrees per 100 feet was the Allison Well which is located south of the Rift Zone. If absolute temperatures are used to construct a map, it shows that the highest temperatures occurred in the Rift Zone(See Figure 14).

Two microearthquake studies were conducted for short periods in the Lower East Rift. The first survey was conducted in 1973 for a two week period. During the survey, 38 earthquakes were recorded(See Figure 15). Interpretation of this study indicated that a cluster of shallow earthquakes were recorded around where HGP-A was ultimately drilled (Suyenaga, 1978). The results of the study are in agreement with the generally accepted theory that the occurrence of earthquakes can be related to reservoir permeability.

The second survey was conducted in 1976 by Microgeophisics, Inc. Their survey was shorter and it showed an interesting result. There were so few earthquakes recorded that an areal trend could not be discerned. What earthquakes were recorded were fairly evenly distributed. The analysis was carried one step further to the calculation of Poisson's Ratio. This is supposed to measure the susceptability of rocks to fracturing: increasing values of Poisson's Ratio would mean more fracturing and more reservoir permeability. Figure 16 shows the results of this analysis. Poisson's Ratio is highest where the two unsuccessful wells were drilled and reservoir permeability was low. This additional analytical step clearly did not help to find a resource. It is very possible,however, that the low number of events could have led to the erroneous conclusions.

Related fairly closely to microearthquake surveys are ground noise surveys. The concept is that noises at certain frequencies are caused by subsurface events such as ground cracking. Such a survey was conducted by Dr. Wayne Suyenaga in

1974(HGP Report,1975). His conclusion was that the most favorable location for a geothermal well was near Puulena Crater. This is almost precisely the site where the Lani Puna well was drilled, and it was a dry hole.

Geochemistry is frequently used as an exploration screening device to determine whether the source reservoir of interest has sufficient temperature to be considered commercial. Analysis of water samples from wells around the Lower East Rift indicate that the waters feeding the wells have some relationship to a geothermal aquifer(Cox,1979). However, attempts to quantify resource temperatures using conventional geothermometers were unsuccessful. Water from HGP-A was analyzed and indicated a temperature of 240 degrees C, sufficient for a commercial reservoir, but considerably less than the actual temperature of 320 degrees C.

Another frequently used geophysical measurement is self potential(SP). This measurement indicates areas where an electric potential is being generated, usually due to ion exchange or fluid movement. A series of SP studies were performed by Zablocki(1974) in the East Rift. A very prominent SP anomaly was identified in the Lower Rift as shown in Figure 17. Theoretically, drilling on such an anomaly is desireable because circulating fluids could indicate the presence of a convection zone. The results show that the three successful wells were drilled off the anomaly. A dry hole, Lani Puna was drilled closest to the anomaly. Like the others, SP proved to be unreliable as an exploration tool.

In summary, the results of the drilling demonstrate that:

(1) A commercial resource does exist within the East Rift.

(2) Every geophysical tool used in the East Rift except aeromagnetics and microearthquakes, failed or gave misleading results.

(3) Temperatures necessary to have a geothermal resource occur at drillable depths.

(4) The geothermal reservoir in the East Rift is heterogeneous such that commerical and non-commercial wells can be drilled within relatively short distances.

(5) Wells drilled in the northern half of the Rift Zone were successful, those in the southern half were not.

(6) A description of the East Rift geothermal reservoir can be inferred from existing wells.

3.4 INTEGRATION OF DATA: KAHAUALE'A AND LOWER EAST RIFT

Information from Kahauale'a, the geophysical studies of the Lower East Rift, and the results of well drilling can be combined to show evidence of a viable geothermal resource at Kahauale'a. It is clear that the East Rift Zone is productive of geothermal fluids. Geothermal drilling planned by the True/Mid-Pacific Geothermal Venture will be conducted in this identical geological feature. A reasonable assumption is that the general geologic characteristics of the East Rift vary only slightly along its length. The first well in Kahauale'a(KA-1), will be drilled 12 miles away and up the Rift Zone from the closest commercial well. If KA-1 is successful, it would have an enormous impact on the State because it would extend the productive area for commercial geothermal energy far beyond its current limits.

A feature common to the three successful wells drilled so far is that all were drilled north of the Rift Zone centerline. KA-1 is also planned for north of the centerline. The two unsuccessful wells were drilled south of the centerline.

Moreover, as observed in the microearthquake studies of the Lower East Rift Zone, the successful wells were drilled in areas of more earthquake activity than the unsuccessful wells. Referring to the microearthquake study in Kahauale'a by Dr. Helsley, there was substantially more earthquake activity in Kahauale'a than in the Lower East Rift per unit of time.

Suyenaga	1.6 events/day
Microgeophysics	1.6 "
Helsley	5 to 7 "

Thus the larger number of seimic events detected at Kahauale'a suggest that the potential reservoir should be more fractured than the Lower Rift.

As mentioned earlier, temperature gradient holes are not practical at Kahauale'a due to lack of accessibility and the fact that a large diameter hole would have to be drilled to reach sea-level at depths of more than 2500 feet. Thus a large size rig would be needed necessitating an access road that is not now available.

Geochemical studies require a source of ground water that does not exist in Kahauale'a.

Electrical geophysical measurements could be conducted in Kahauale'a, but considering the experience in the Lower Rift Zone, such studies do not offer the prospect of positive results. Drilling on low resistivity anomalies or SP anomalies do not guarantee a successful well. Primarily, this is attributed to their shallow depth of investigation. Manipulation of the raw TDEM data to estimate resistivity in deeper zones has been attempted without success(Kauahikaua,1982). This study which used the old TDEM data, showed much larger and broader resistivity contours(Figure 18). This is because resolution becomes more difficult as depth increases. The result is not useful because it shows that all five wells were drilled in the same low resistivity feature.

Self Potential studies have similar depth limitations and ground noise measurements failed to locate a resource.

Other studies that were conducted such as magnetic, gravity, and photogeologic confirmed the location of heat which is basically confined to the East Rift Zone. Thus these studies were not considered to be very helpful to define the location of a drillable resource.

Because the geothermal resource at Kahauale'a is even deeper than in the Lower Rift, geoelectric studies will be even more unreliable and misleading. Conducting such studies is considered to be a total waste of money. In the Lower East Rift Zone, a successful well(HGP-A) can be less than 2500 feet away from an unsuccessful well(Lani Puna). There is no tool available for a geothermal exploration program that can discriminate to such fine detail at depths of 8000 feet. True/Mid-Pacific has considered a different method called magneto-tellurics to solve the depth resolution problem. Under the right conditions, this tool can provide a resistivity profile to great depths. Magneto-tellurics depend on the measurement of natural electrical and magnetic fields that occur in the area of interest. Unfortunately this method was considered to be inappropriate since experience has shown that natural signals in the East Rift Zone are so weak that reliable differences from place to place are very difficult to measure. Thus the technique would have little accuracy or resolving power and be no better than the electrical techniques attempted in the Hawaii Geothermal Project.

At this point, there is sufficient evidence to justify the expenditure of substantial funds to drill a geothermal well. Generally studies are much less expensive than drilling, such that, if there were studies that could eliminate drilling of an unsuccessful well, they would be conducted. There is no reluctance to perform a study that would provide useful information, but the evidence shows that all practical work has been done at Kahauale'a. It has better heat flow and better microearthquake results than the Lower Rift. The geology is similar and the proposed drilling locations are north of the Rift Zone axis. The probability of a successful well in Kahauale'a should be greater than the 60% success factor for all wells drilled in the East Rift Zone. All that there is left to do is to drill a well to confirm the resource.

4.0 SCHEDULE OF ACTIVITIES

4.1 TIMING CONSIDERATIONS. The time schedule to conduct exploratory drilling in Kahauale'a depends on the resolution of certain contingencies currently in the process of resolution. Therefore the Project Schedule shown in Figure 19 is a relative schedule defining the sequence of activities and the estimated time to accomplish these activities once these contingencies are resolved.

Once a management decision is made to proceed with exploration drilling, it will require four months to mobilize a drilling rig to Kahauale'a. This is the critical path to earliest completion of the project. Because of the timing uncertainty, the drill rig may be contracted out when the decision is made. For this reason a one month period has been estimated to allow the rig to complete its current well and return to Casper, Wyoming, for geothermal modifications. After the necessary modifications, including the extension of the sub-base to accomodate the required blowout prevention equipment (BOPE), the rig will be trucked to Oakland, crated, and placed on a ship for Honolulu and then transshipped to Hilo. A one month period has been allowed for shipping to account for a possible waiting period while transportation is arranged.

All special supplies and equipment such as bits, mud, air compressors, mufflers, and logging units will also be shipped with the rig. General supplies will be purchased in Honolulu or Hilo.

4.2 RIG MOBILIZATION TO KAHAUALE'A. Once the rig arrives in Hilo, conventional rig up procedure will be followed. This means placing the equipment as shown in the layout in Figure 20. The mast will be erected and all electrical and piping connections made. The access road, well pad, and conductor pipe installation should be finished prior to arrival of the drilling equipment. All operating personnel will be settled and prepared to begin work prior to arrival of the rig. A security station will be posted at the entrance to Kahauale'a.

The first well will require 2-1/2 months to drill to a depth of 12,000 feet or until a commercial resource is encountered, whichever is shallower. After drilling, a short term well test will be conducted. This will be followed by a longer term test once the rig moves to the next well site.

The Project Schedule shows all the necessary Plans required to be submitted prior to start of operations. Also, peripheral activities such as air quality monitoring, and special tests such as noise evaluations and water sampling, are shown at the time that they are required. The meteorological station located in Fern Forest Subdivision is currently in operation, and it will continue to collect data. In addition, an air quality monitoring survey discussed in Section 7.0, has been initiated.

The number of wells, within the allowed limits of the D&O, that will be drilled cannot be decided upon at this time. This will depend on the results of the first few wells and an updated resource evaluation when well test data is available. The schedule shows a continuous drilling program, however, if the drilling results are unusual, a brief hiatus in drilling activity may occur. During such a period, preventive maintenance work will be performed on the drilling rig.

5.0 DRILL SITE SELECTION.

5.1 SITING CRITERIA. The initial geothermal well(KA-1) in Kahauale'a will be sited close to the location specified in the Project EIS(See Figure 21). This site was selected because:

-it is close to the center of the East Rift Zone and the predominant heat source

-it is within a zone of frequent microearthquake activity

-it is close to a surface fault similar to the successful wells

-it is north of the Rift Zone axis

-it is away from possible cold water intrusion

-it is on a lava flow which minimizes the impact on vegetation

-it is furthest away from populated areas which minimizes air and noise impact.

The proposed location of KA-1 is 4000 feet east and 16,750 feet south of the northeast corner of Kahauale'a. Proposed total depth of the well is 12,000 feet or until a commercial geothermal resource is encountered, whichever is shallower. A straight non-directional hole is planned for KA-1. If the well is successful, the drilling rig will be moved to Well Site 2, which is located about 3000 feet to the north. KA-2 will also be drilled as a straight hole to a depth of 12,000 feet. If KA-1 is unsuccessful, it will be redrilled directionally in an attempt to intersect a fracture system. If unsuccessful again, a rig move to Well Site 2 will be considered.

If the first two wells are successful, the rig will probably be moved to Well Site 3 providing current volcanic activity has subsided. This location will act as a confirmation well to determine the extent of the resource and prove that the reservoir model is reasonable. Following KA-3, the rig may be moved to Well Site 4 if volcanic activity has subsided. The drilling sequence and well locations are subject to change as drilling results become available. A definite well by well schedule cannot be developed without an intricate decision tree with many assumptions on possible outcomes of drilling. It is the intent of the Developer to minimize the number of wells required to determine the nature and extent of the geothermal resource beneath the Permitted Area.

5.2 DRILLING PROGRAM. Wells at Kahauale'a will be drilled using a conventional rotary rig rated from 12,000 to 16,000 feet. The planned well completion calls for a string of 7 inch slotted liner to be installed across the productive intervals. The liner will be hung from a string of 9-5/8 inch casing set at about 6000 feet that is cemented back to the surface. A schematic of the planned completed well is shown on Figure 22. A total of 2-1/2 months has been estimated as the time required from spud to completion. Equipment to drill the well will be furnished by True Drilling Company. This rig will be equipped with all required safety equipment to protect against well blowouts and provide a safe working environment. A detailed drilling program for KA-1 is included in Appendix B. This program was developed by Mr. Louis E. Capuano of ThermaSource, Inc., which is the Developer's Drilling and Reservoir Engineering advisor. Mr. Capuano has had extensive experience in drilling geothermal wells in The Geysers, Hawaii, the Basin and Range, and Costa Rica.

Drilling operations will be supervised by two experienced rig pushers from True's current staff. An experienced drilling crew will be provided with the rig. Day to day surveillance and planning will be managed by an Operations Supervisor under Mr. Gary Hoggatt, the Project Coordinator. During critical operations such as casing setting or fishing, Mr. Capuano will provide on-site supervision.

During the drilling of each well, a complete and continuous log of the drilling activities will be kept. Professional mud loggers will describe the rock cuttings, monitor gases, detect changes in fluids, and record mud temperatures. A professional geologist will provide the necessary consultation to pick casing points and correlate drilling progress with the reservoir model.

A complete suite of geophysical logs including induction, SP, density, sonic, gamma ray, neutron, and temperature will be run as practical to do so, given the anticipated temperatures. Wireline spinner, temperature, and pressure surveys will be conducted at appropriate times to determine the productive intervals, pressure and temperature variations with depth.

5.3 WELL TESTING PROGRAM. An extensive well testing program is planned for each of the early wells. Preliminary rig tests of several hours duration will be conducted with the James Lip Pressure method. The main purpose of this test will be to acquire data to complete the design of a long term test. Static pressure and temperature surveys will be taken prior to starting the long term test. For this test, well fluids will be produced to a steam/water separator and then into a muffler or rock sparging pit. Usual well performance parameters of mass flow, quality, pressure, temperature, steam enthalpy, H2S content, and non-condensible gas/steam ratio, will be measured. Full well stream samples will be taken for chemical analysis. Water samples from upper zones will also be taken to determine chemical composition and to understand the hydrology of Kahauale'a. Wellhead expansion and contraction measurements will be taken for pipeline design purposes. Prior to conclusion of the flow period a flowing pressure and temperature profile will be obtained. The measuring instruments will remain in the well after the well is shut-in to obtain buildup pressures. Based on HGP-A pressure recovery, a build up period of 7 days is anticipated. A decision to use conventional Amerada gauges or a capillary tube will be made after the Lip Pressure test. Special multiple well testing may be conducted once sufficient wells are available. Interference tests and tracer surveys are the most common types of test to determine communication between wells and the orientation of fracture systems.

Mr. Gerald Niimi of ThermaSource, Inc. will supervise the well testing and analyze the data. Application of pressure transient analysis to geothermal wells is common practice and reasonable results can be obtained to describe the reservoir. Information such as permeability-thickness or transmissivity, skin damage, reservoir pressure, fracture location if present within the drainage radius, and fracture spacing are possible to obtain.

Data from the well will be used to update the reservoir model and guide further exploration of Kahauale'a. Later, given the appropriate permits, confirmation and development wells should provide an improved understanding of the full potential resource.

Conduct of the well tests will comply with conditions of the BLNR Exploration Permit. As such, noise levels during the test must be maintained at or below 55 db at the leaseline. The use of mufflers and sparging pits should adequately reduce noise to mandated levels. Hydrogen sulfide abatement systems will be used to maintain emissions below 2.5 kg/hr. Current practice is to inject caustic soda into the well flow line to neutralize hydrogen sulfide in the flow stream. Equipment to do this will already be on-site because H2S abatement must also be performed during the drilling phase. Monitoring at various sites within and outside Kahauale'a will be conducted during the well tests to obtain information on the dispersion and level of emissions.

what will ambient air be?

A complete well test program with schematic diagrams showing the measurement points and equipment layout is provided in Appendix C.

6.0 ORGANIZATION AND PERSONNEL

In order to manage the Kahauale'a Geothermal Project, a competent staff of full-time Campbell Estate and True/Mid-Pacific personnel and a group of qualified technical advisors has been assembled. Members of the management team are as follows:

a. Estate of James Campbell

   Director of Hawaii Operations - Russell Alger

b. True Geothermal Energy Company

   General Partner - H. A. "Dave" True, Jr.

Project Manager (Operations) - H. A. True, III

Project Coordinator - Gary Hoggatt

Hawaii Representative - Allan G. Kawada

c. Mid-Pacific Geothermal, Inc.

President - John P. Ellbogen

Executive Vice-President and Hawaii Representative - R. B. Moss

Vice President - Steve C. Champlin

Secretary - William F. Drew

The organization responsible for day to day operations during exploration drilling is shown on Figure 23. Mr. H. A. "Dave" True is the Managing General Partner of the Project. Mr. Hank A. True III is the Project Manager, and has the authority to act on behalf of the True/Mid Pacific Geothermal Venture. Mr. Gary Hoggatt is the Project Coordinator. He is currently a Drilling Engineer in the True Drilling Company, but will be assigned to work on the Kahauale'a Project. Other members of the organization include Mr. Allan G. Kawada, currently the Hawaii Representative for True, who will be in charge of the administrative functions once drilling begins.

An office will be established when field operations begin. An Operations Supervisor, yet to be named, will head this office. This person will supervise the day to day drilling operations and provide the necessary liaison between the Project Coordinator and the Field. The Operations

Supervisor will also investigate complaints and try to resolve any problems that may arise because of the drilling activity.

Reporting to the Operations Supervisor will be the 15 member rig crew. This represents three complete crews of 5 men each. The crew consists of a Driller, Derrickman, Motorman, Floorman, and a Roustabout. Initially at least 12 of the 15 members will be recruited from the current True organization, while use of Big Island residents will depend upon a number of factors such as the actual scope of the drilling program, availability of applicants, etc.

Technical advisors for Geology, Drilling, and Reservoir Engineering will be called upon as needed during critical phases of Field Operations. The best qualified people in the geothermal field will be retained for these functions.

7.0 ENVIRONMENTAL IMPACTS

7.1 GENERAL. Exploration of the permitted area will be impacted by land clearing and construction activities and well drilling and testing. Because of the limited scope of the activity in terms of number of wells and area, the environmental impact will be very minor. The greater impact will occur during the construction of the access road. Once that activity is completed, impacts will be very minor and consist mainly of noise and air quality impacts. Much of the discussion described herein was extracted from the Project

EIS. Also there is some overlap with Section 7.0 because safety considerations are directed toward preventing environmental impacts.

7.2 ACCESS ROAD. The access road from the Volcano Highway to the initial well site will follow the planned route described in the EIS and shown in Figure 21. An easement through the Shipman Property between Kahauale'a and Volcano Highway has been acquired. This route was selected because it avoids the heavy concentration of adenophorous periens located in the northeast section of Kahauale'a, it has minimum exposure to lava flows, and is only slightly longer than other routes considered.

Roads from the south through Royal Gardens Subdivision and Campbell Estate property would minimize disturbance of closed canopy ohia forest, but would in fact provide maximum exposure to volcanic hazards. Relying on a road from the south as the primary access road would, therefore, not be feasible. Such roads would be impassible now due to current eruptive activity. In addition, work vehicles and truck traffic would be routed through a residential area if the Royal Gardens Subdivision route were selected. Moreover, the topography of the southern portion of Kahauale'a has an extreme incline in the northerly direction which would make it undesirable as the primary access road over which heavy loads are moved into the project area. In order to alleviate this problem, any road from the south would have to be constructed in a alternating zig-zag pattern in an east-west direction.

Since the Royal Gardens Subdivision road is already constructed in a north-south direction, it was eliminated from consideration for safety reasons. An alternating zig-zag road would be much longer and therefore, much costlier than a straight line road to reach the same distance into Kahauale'a. Forest clearing and environmental disturbance would therefore be maximized. These considerations also worked against selection of any road from the south of Kahauale'a. The distance would have also been longer than the road from the Volcano Highway.

The main population of the adenophorous periens appears to be concentrated in the central and northeast sectors of the northern portions of Kahauale'a. The roads from Captain's Drive and from the center of Fern Forest Subdivision would disect the highest density populations of the adenophorous periens to directly reach drill site KA-1. Moreover, the access corridor through Fern Forest Sub-division would have necessitated negotiating a legal easement through the Sub-division. There are no County of Hawaii or State of Hawaii roads through the area. True/Mid-Pacific Geothermal Venture was involved in negotiating with the Fern Forest Community Association. The Developer offered to improve and maintain the "upper road" through Fern Forest in return for the easement. However, an easement could not be acquired despite extensive attempts at negotiations, due to the fact that the Developer would have been required to obtain an easement or consent from each of the owners in the Sub-division.

Another corridor coming though the Shipman Estate Land directly to drill site KA-1 but going diagonally across Kahauale'a in a southeasterly direction was considered. Similar to the Captain's Drive and the Fern Forest Subdivision alternatives, this potential corridor is imprudent since it would have divided the center of the highest density populations of adenophorous periens to reach drill site KA-1. In addition, the roads through Captain's Drive and Fern Forest Subdivision would have necessitated travel through populated residential areas causing impacts that could be avoided by the selection of the Shipman Estate corridor.

The road selected for the project as shown in the EIS will be located on the edge of the adenophorous periens population areas and will avoid routes that will cut directly through the center of the area of densest populations of the fern where a diagonal road would intersect the denser population earlier than if the preferred route is used.

After considering all the alternatives, the original route selected for the project still remains the optimum choice.

The initial access road will be designed for low speed movement of trucks and trailers to the drilling sites. The design of the roads will be submitted for County approval. It is planned that the road will be constructed in two phases. A logging road will involve clearing of vegetation to a width of 18 to 20 feet, with some turnouts for passing; areas will be leveled as required. In the second phase, the road bed, approximately 12 to 14 feet, would be made more permanent by additional grading of on-site pahoehoe lava, and adding a limited amount of aa lava fill material where required to develop a suitable roadway. Since the aligment is well drained, drainage ditches will not be required except in those limited bog areas that may be encountered. A minimum of excavation and embankment is anticipated due to the gentle slope. A ground survey team of experienced surveyors, civil engineers, archaeologists, and botanists has already determined the suitability of the initial access road from Volcano Highway to the original KA-1 site. Any changes in route must be validated by a road alignment team prior to construction.

The construction of the initial access road will follow existing practices for road construction on lava flows on the Big Island. Two large bulldozers in series will go down the road alignment to clear away vegetation and crush any loose lavas. A road grader will smooth and shape the 14 foot roadway and build the required ditches and turnouts.

Other potential impacts due to land clearing and access road construction will be minimal and are listed as follows:

-Land Use:	access road	18 acres
	4 drill sites	20 acres

Total area 38 acres

-Surface and ground water quality: No impact because there are no streams, rivers, or lakes

-Air quality: Temporary dust and debris caused by construction

-Noise: General noise from operation of construction machinery for a period of two months. Maximum noise levels will occur during early stages of construction while closest to housing areas.

-Fauna: With little clearing over a large area, the impact on fauna, mainly feral pigs and birds will be minimal.

7.3 DRILLING AND WELL TESTING. The D&O allows up to 8 wells to be drilled within the Permitted Area. The major potential impacts of drilling and testing geothermal wells could be derived from noise during drilling and testing, H2S emissions, discharge of geothermal fluids on the ground, loss of drilling mud into subsurface formations, and a well blowout. The latter is not considered very likely because of the safety precautions that will be taken and are discussed in Section 8.3.

To mitigate noise, exhaust systems will be equipped with hospital type mufflers. A drilling muffler will be utilized during air drilling and testing to reduce the noise associated with steam venting. The Developer also has committed to meeting the County noise guidelines except for short period initial venting of the wells in which case approval from the BLNR will be attained beforehand, and abiding by the conditions in the D&O. Hydrogen sulfide emissions during drilling and testing will be kept to less than 2.5 kg/hr by injecting caustic soda into the flow line. An extensive monitoring and logging program will be maintained so rig personnel will have all the information necessary to avoid potentially hazardous conditions.

An air quality monitoring proram will be in place to determine the effect of H2S emissions during drillling and well testing. BLNR will receive copies of all reports and thus will be able to ascertain the impact of the well testing on air quality. In addition to H2S, this monitoring program will also detect emissions of radon, SO2, mercury, and total suspended particulates (See Section 7.5).

As far as visual impacts are concerned, the drilling rig may be visible from limited view corridors while on open lava flow. Low intensity lighting will be used to commensurate with worker safety to reduce visual impact at night. Since the Permitted Area is very remote, and the rig will move from place to place, the rig will be difficult to locate from Volcano Highway. A steam plume may be visible during well testing and drilling, however, it should look like a small brush fire or natural vent.

7.4 METEOROLOGICAL DATA. A meteorological station has been collecting baseline weather data in Fern Foest Subdivision since August 1982. Data being collected include wind speed and direction, temperature, humidity, and rainfall. The station is located approximately 3-1/2 miles from the initial drill site, but it is believed that the data substantially represent actual conditions in Kahauale'a. This data will be useful as baseline information for dispersion modeling of H2S emissions and noise propagation studies. A station within Kahauale'a will be installed immediately after an access road is constructed.

7.5 AIR QUALITY MONITORING SURVEY. The Developer has begun an air quality monitoring survey as specified in the D&O. NEA, Inc., of Beaveton, Oregon, has been contracted to gather meteorological data and monitor the natural emissions of various substances. NEA, Inc.,is the same company that is doing the environmental survey for the State of Hawaii. The program for Kahauale'a consists of a mobile station equipped with meteorological instruments and monitors to detect the presence of SO2, H2S, mercury, total suspended particulates and radon. Periodic rain water samples will be collected and analyzed. This station will be in operation continuously and rotated between seven (7) areas on a six (6) day per station basis. Stations will be located in the National Park and in communities surrounding Kahauale'a.

In summary, the Developer is commmitted to a program that will satisfy environmental concerns and has preinvested funds for baseline studies. Additional Plans as required by the D&O will address individual topics in more detail.

8.0 SAFETY AND HAZARDS ASSESSMENT

8.1 SAFETY POLICY. True Geothermal Energy Company, as operator, considers safety as one of its highest priorities. The company safety policy says:

> "True, owners, management and middle management, firmly believe that the continued success of any organization, or the successful completion of any project, can be achieved it is done safely.
>
> We realize the need to have quality people who have a positive attitude toward doing their jobs safely, with proficiency and with great concern for the safety and health of fellow workers."

In order to promote safety awareness, management is committed to a program of regular safety meetings at least once a month, for both the field and office staffs. At these meetings, personnel will receive training and lectures on the proper methods to handle hot valves, wellheads, pipelines, and bleed lines so that they will not provide a source of injury. In addition to heat, H2S safety must be emphasized. Personnel must be trained to use the breathing equipment and recognize the danger signals. First aid and C.P.R. sessions will be held periodically. Regular updates to the evacuation plans will be presented. A pyramid telephone calling will be utilized to notify personnel.

Many incentives are offered for safety such as monthly glove awards, yearly coverall awards, and yearly personal awards for drillers and toolpushers.

Although a drilling operation has historically been considered a dangerous workplace, the record of True Drilling Company has been truly exemplary. True Drilling Company is a long time member of the International Association of Drilling Contractors. Awards received from this organization for safety include:

1975	1st Place Class A Land
1976	2nd Place Class A Land
1977	1st Place Class A Land
1978	1st Place Class A Land
1979	1st Place Class A Land
1980	Honorable Mention Class B Land
1981	Honorable Mention Class B Land

Thus it has been proven that constant supervision and safety awareness can provide superior results.

8.2 SECURITY AND COMMUNICATION. As previously mentioned, a security gate will be constructed at the entrance to Kahauale'a. The gate will help to assure that vehicular traffic can be controlled to only authorized vehicles. With controlled access, damage to the natural environment by visitors or vandals will be minimized. Also people who are allowed on the property can be held accountable for their action. It is the intent of the Developer to maintain strict standards of conduct because of the conservation district classification and the possibility that dangerous conditions could occur.

8.3 SPECIFIC SAFETY CONSIDERATIONS. The drilling rig will be equipped with proper blowout prevention equipment to prevent uncontrolled release of well fluids. Blowout prevention is approached from four aspects: proper equipment, proper mud weight, proper training, and experienced supervision. Equipment currently being recommended are ram-type preventers with blind and pipe rams and bag-type preventers. Also essential to blowout prevention is good cementing of intermediate strings of casing. If the casing is not properly cemented, blowouts can still occur even with proper surface equipment.

The use of proper mud weights to balance reservoir pressure is necessary to drill under controlled conditions.

Too light a mud may speed drilling, but could be inadequate to suppress a sudden gas entry.

Proper training of crews on how to recognize impending blowout conditions and how to correct these conditions is of utmost importance. An alert, experienced crew can handle all blowout conditions as part of their normal duties. Primarily the crewmen must recognize the symptoms of an impending blowout and then take corrective action. If this is done, conditions should return to normal in a short time. Like a trained crew, competent rig supervision is very important. The rig supervisor or pusher is responsible for training the crew and insuring that safe practices are followed. The pusher also makes sure that all equipment is properly maintained so that it will do its job when an emergency arises.

In order to operate safely, the drilling equipment must be rated to perform the job. Most rigs are usually over designed so that they can drill 20% to 25% over their rated depth. Thus a rig nominally rated for such 12,000 feet can drill to 15,000 feet without any problems. However, if drilling problems occur, such as stuck pipe, an undersized rig may not have the capacity to get out of trouble. Whereas with a slightly oversized rig, minor drilling problems can be overcome with little difficulty. Current plans call for a rig rated between 12,000 and 16,000 feet. This size of rig should be more than adequate to drill safely to 12,000 feet.

Since it has been reported that high wellhead pressures were detected on the Puna Geothermal Venture wells, all wellheads, valves, and pipelines will be designed to withstand at least 2000 psi. Because of the extreme heat and gas content of the well fluids, most equipment must be derated below their name plate value. It is intended that 2000 psi or higher rated equipment will be used to provide a margin of safety.

In geothermal drilling, particularly while using air, drill pipe will wear quite heavily. Thus frequent inspections of each length of drill pipe are conducted to detect stress cracking, corrosion, and general wear and tear. All tool joints are beefed up to provide a heavier wall to guard against erosion due to cuttings abrasion. A magnetic particle inspection unit will be brought over from the Mainland to provide pipe inspection services. In addition to drill pipe, all casing is inspected twice, once on the Mainland and once before being used. This will guard against defective pieces of pipe being installed and creating a source of leaks.

8.4 TEMPORARY DRILLING SHUT-DOWN. One of the concerns while drilling is the threat of a lava flow covering the well site.When an eruption occurs and a lava flow is impending it is essential that drilling personnel be moved to a safe location and the well closed-in. This will insure that proper plugging may occur at a later date or drilling resumed after the emergency is over.

Temporary shut-downs of drilling operations are not an unusual requirement. In many areas of the world, conditions exist where a sudden shut-down is a constant threat. Such conditions include hurricane, rough seas, political unrest, earthquakes, or volcanic eruptions. The drilling industry has responded to these threats with technology and tools to secure wells that are in various stages of drilling or completion in relatively short periods of time. These tools, commonly referred to as "storm plugs" or "bridge plugs" are stored at the drilling site so that installation can occur on short notice in the event of an impending hazard.

In the event of an eruption or impending lava flow, the Operations Supervisor will be in constant communication with Hawaii Volcano Observatory(HVO) so that the immediate threat to the drilling operation may be assessed. This should determine how much time is available to secure the well because temporarily closing-in a well depends greatly on the depth of the well. Depending upon this time estimate, a plan can be designed to ensure the safety of all personnel, as well as the security of the hole and drilling equipment. If sufficient time exists, steps could be taken to allow removal of expensive drilling equipment to a safe location. Once a plan of action has been undertaken, the Operations Supervisor will maintain contact with HVO to monitor the development of the emergency as it proceeds, to determine if the chosen plan of action should continue or be amended.

The number one priority of this plan and the overall drilling operations is the safety of all personnel, both employees and the general public. All procedures detailed below are written with the priority of safety as the most important factor.

The next order of priority is to leave the wellbore in a safe condition. The wellbore can be isolated from the surface safely and quickly with the installation of a bridge plug or storm plug. The oilfield tool is inserted into the wellbore on the drill pipe and set at any depth in the casing. The drill pipe below the plug can be safely suspended from the plug. The drill pipe above the plug can be unscrewed and removed or left in place. By installing this plug into the wellbore and closing all surface wellhead valves the hole can be isolated to prevent movement of fluids or gases from the lower potentially productive zones to the surface as well as prevent surface fluids from moving down the hole(See Figure 24).

The bridge plug is built to withstand high pressures and temperatures and is available in various sizes. Bridge plugs, and many tools similar to them, are found at drilling sites worldwide where possible hazardous conditions exist. Drilling plans call for plugging tools such as these to be kept on-site at all times while drilling below the 13-3/8" casing string. All rig personnel will be familiar with all aspects of running and setting these tools, so that if an emergency occurs the wellbore can be safely secured and isolated before personnel leave the rig. These tools can also be easily removed after the hazardous condition has ended and drilling operations are resumed. All valves, wellheads are tested at the factory to hold pressure at 2,000 PSI and designed to withstand temperatures in excess of 2,500 degrees F. compared to 2,000 degrees F. lava temprature. In the event that the entire wellhead assembly is destroyed by a massive flow, the subsurface plug would provide a backup to isolate the well from the lava. Should a lava flow damage a well and drilling is no longer feasible, the well can be properly plugged by setting the required cement plugs above the bridge plug.

The last priority, if time allows, would be the drilling equipment. Certain portable pieces of drilling equipment and rig components could be removed and relocated to a safe area if time permits. These components should be chosen and listed beforehand. That is, a priority list of equipment should be prepared and the list kept on location at all times in the event of evacuation. Appendix D is a priority list of equipment that will be kept on location at all times in the event of evacuation. Trucks and cranes necessary for a move should be prearranged so that they will be available in the event they are needed.

The following sequence of operations should be followed in total or in part, based on the time factor allowed by the emergency condition. It should be kept in mind that Hawaiian lava flows are non-explosive and therefore good estimates of lava flow direction and speed can be made.

(1). Assess the emergency, consulting with local agencies to determine speed and direction of the lava flow. If the situation warrants immediate action, close all surface valves and leave the location.

(2). If time permits, contact cranes and trucks and arrange for removal of designated drilling equipment.

(3). If emergency occurs while drilling, pull up drill string from bottom at least 400 feet, pick up bridge plug and install on drill string. Run bridge plug into hole approximately 300 feet and set and test bridge plug in 13-3/8" casing. If time allows, remove drill string. This procedure requires about one hour to accomplish.

(4). If drill string is out of the hole when emergency occurs, pick up bridge plug and run in hole approximately 300 feet. Set and test plug, then remove drill string above plug if time permits. This procedure requires half an hour.

(5). Close all surface valves and BOPs to isolate well.

(6). If time allows, remove designated drilling equipment with cranes and trucks.

(7). When safe to return, screw on drill pipe, remove bridge plug by turning drill pipe to right, remove bridge from drilling assembly, and resume drilling.

8.5 MEDICAL EVACUATION. In case of an injury at an exploration well site during construction, drilling, or testing, a complete emergency plan will be developed. There will be first aid services to handle minor injuries, but serious conditions that require immediate medical attention must be provided from outside. The closest hospital is located in Keaau. An ambulance will require approximately 30 minutes to make the trip from Keaau to Kahaule'a. This will be the primary method of medical evacuation, however, other methods are available. Private vehicles could be utilized, however the patient would not have the services of a paramedic until the ambulance was met. If a helicopter was available in the area, it could also be used, but this is not very likely. A complete survey and formal contacts with helicopter operators, including the military, is intended once rig mobilization begins.

The threat of severe burns to personnel performing geothermal work is the most serious hazard. Burn victims may have to be transported to Oahu (Straub Clinic) for treatment or even to a recognized burn treatment center such as Sherman Oaks, California.

Although accidents can happen, every effort will be made to ensure that they are kept to a minimum. Management will be providing the leadership necessary to maintain a safe and efficient workplace that workers will support.

8.6 VOLCANIC HAZARDS. Since January 3, 1983, the Kilauea East Rift near Kahauale'a has been active. Eruptions that started at Napau Crater (see Figure 25) and extended eastward to Kalalua, have now been confined to a single source at Puu 'O located in Hawaii Volcanoes National Park close to the boundary with Kahauale'a. Lava flows from Puu 'O have generally gone northeasterly until reaching Puu Kahauale'a. Then because of its elevation, the lava has diverged north and south around its base. The northward flows have entered the planned development area located nearest the Rift Zone. Since no wells have been drilled, the impact has been nil. Lava has entered about half the permitted Exploration Area, but not the first two planned drill sites. As a result, if operations were to start today, there would be no change in operating plans.

The area where the current eruptions are occurring was previously identified in the EIS as having a high degree of volcanic hazard, and thus eruptions were expected. However, an objective of the Kahauale'a Development Plan was to site wells and power plants north of the active Rift Zone. Had the initial wells been drilled in keeping with this stated objective, and the 25 MW Power Plan construced at Site A, the eruptive activity would not have affected the power plant, which is sited on the slope of an old puu for this very reason. Further, because early drilling was planned for areas away from the center of the Rift Zone, it is doubtful that the lava flows would have entered production well sites, or that any wells or pipelines feeding the power plant would have been affected, since the land slopes to the east and south. Active and passive mitigating measures would concentrate on the safety of the power plant and wells, recognizing that some pipelines could be damaged and be temporarily out of operation.

Mitigation measures being considered are: earthen barriers, lava dikes, and lava drainage canals to channel flows to open area. Completed wells will have concrete cellars and covers similar to the HGP-A design. Elevating drill pads a few feet is also a mitigating measure that would deflect the thin and quick flowing lava around the drill site. If ponding occurs, high lava flow may be more difficult to deal with. Therefore the strategy must be to avoid ponding of lava flows.

Before sites are constructed on the new lava flows, activity in the East Rift must subside to a level where it is safe to drill and complete a well without disruption from new lava flows. The exact definition of "subside" is not clear but certain criteria are indicators.

-A dormant period of no activity for approximately three months.

-Harmonic tremors at Kahauale'a return to near their pre-eruption levels.

-An eruption somewhere else in Kilauea.

Consultation with HVO scientists will be conducted in order that the latest information is available before any decision is made. In fact, while drilling operations are under way, the Operations Supervisor will be in contact with HVO so that the maximum lead time will be available to make contingency plans. If an eruption occurs while a well is in progress, advice from HVO will be used to determine the time available before the well is secured and evacuation begins.

In addition to the volcanic activity, the Big Island was subjected to an earthquake that measured 6.7 on the Richter Scale on November 16, 1983. Fortunately no buildings were destroyed in the National Park so that a comparable earthquake is not expected to affect the drilling operations in Kahauale'a.

True Geothermal Energy Company had had an impressive safety record in the past. A stated objective is to perpetuate this record on the Kahauale'a.

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FIGURES

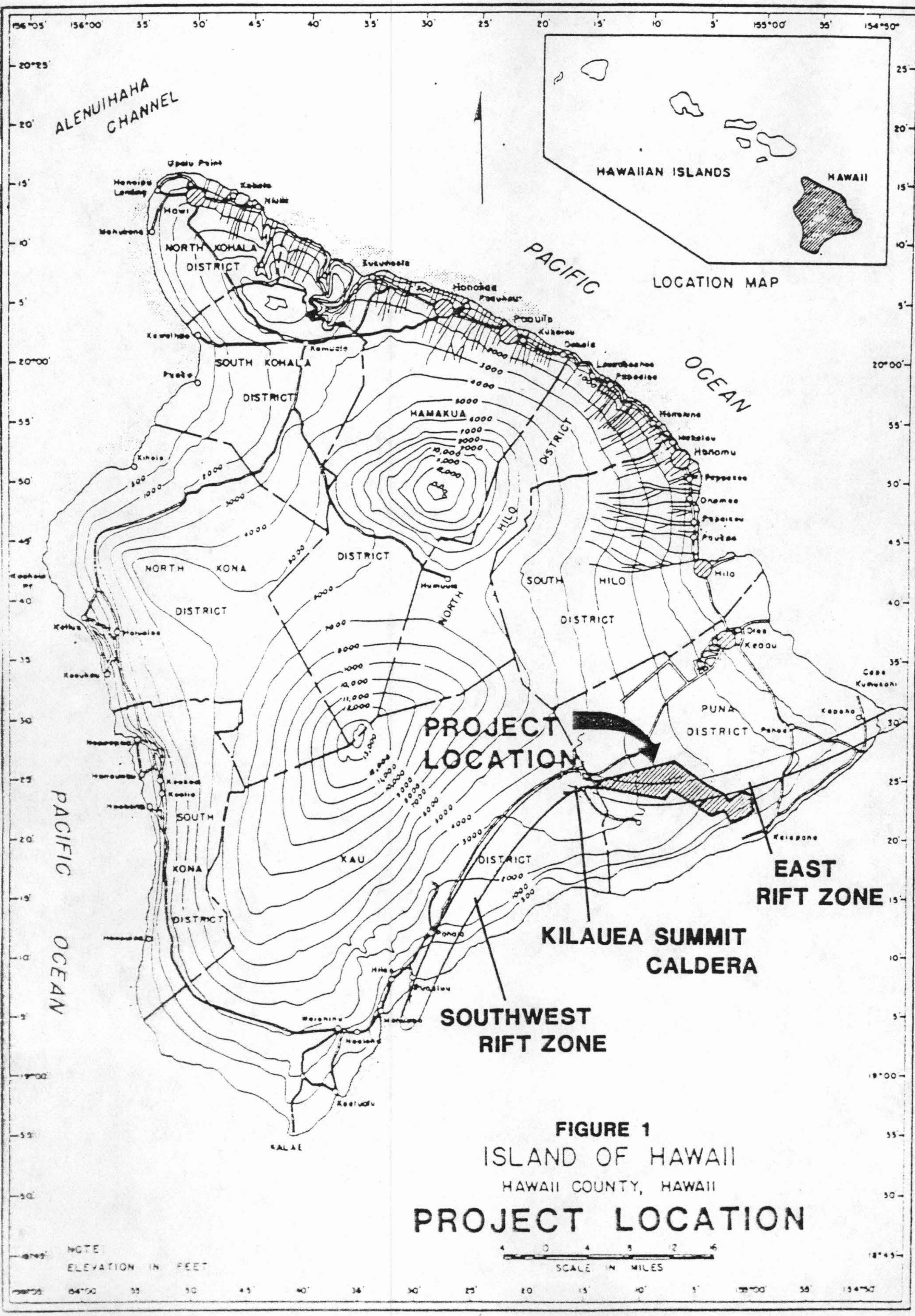


FIGURE 1

ISLAND OF HAWAII

HAWAII COUNTY, HAWAII

PROJECT LOCATION

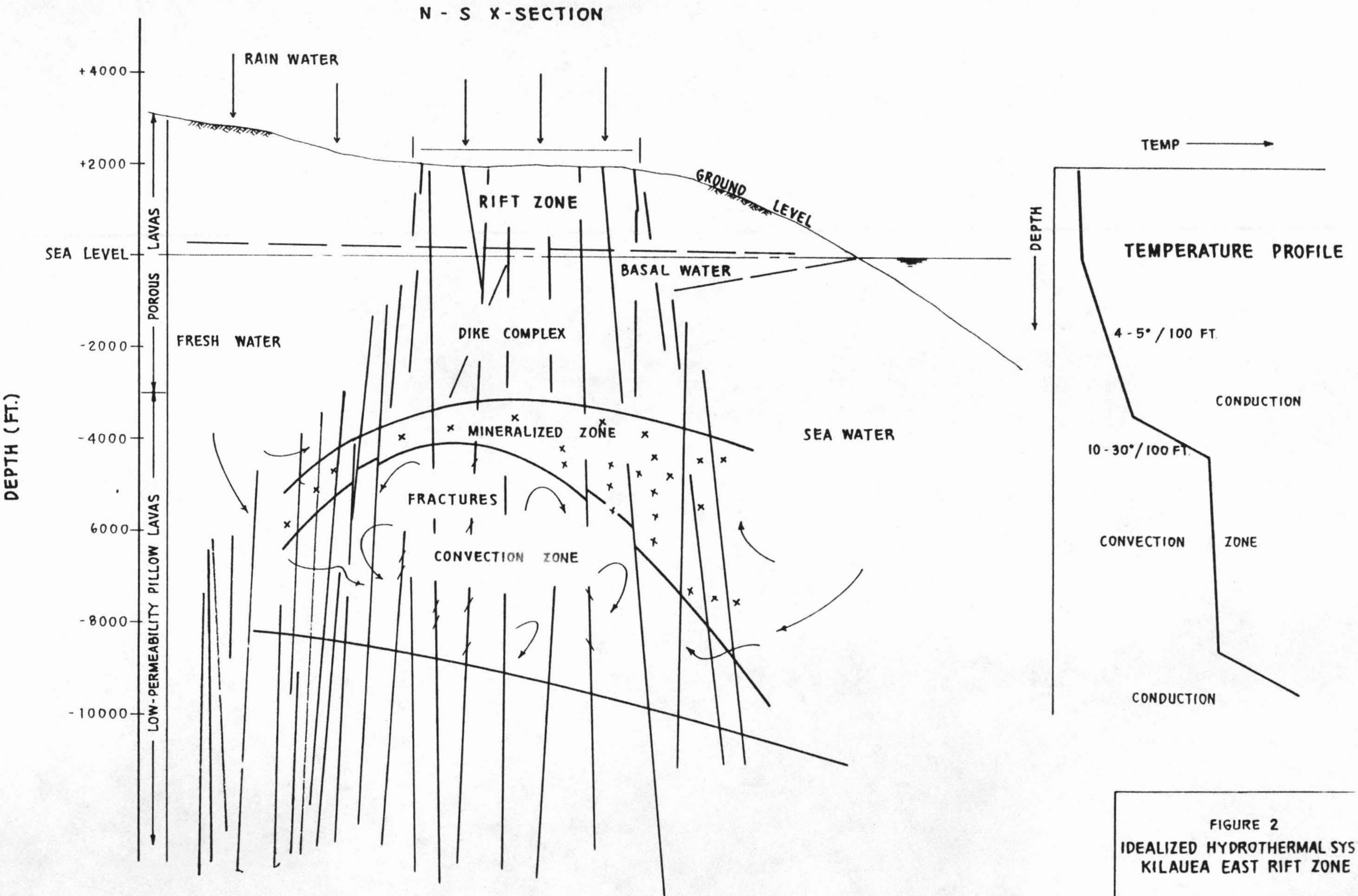


FIGURE 2
IDEALIZED HYDROTHERMAL SYS
KILAUEA EAST RIFT ZONE

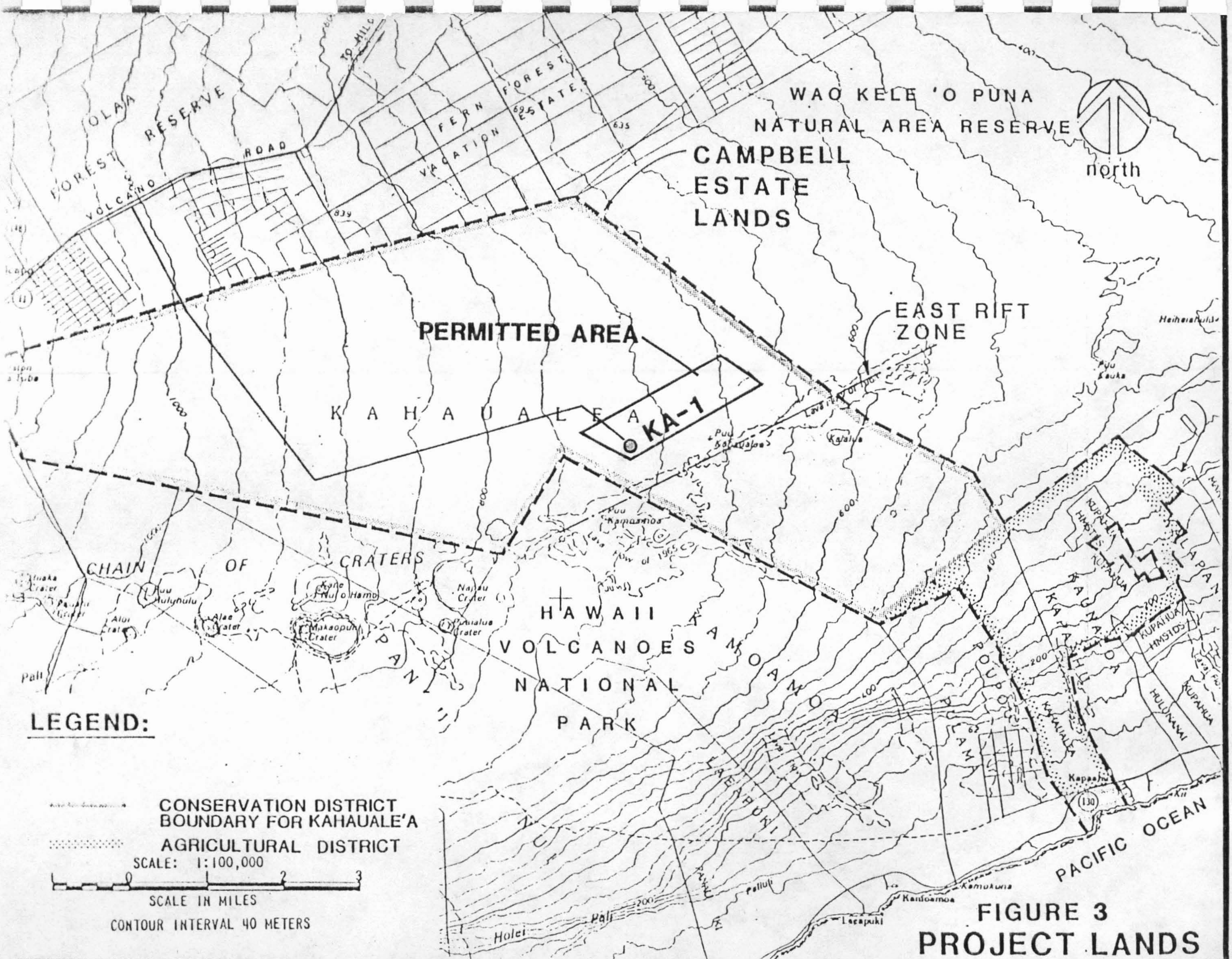


FIGURE 3
PROJECT LANDS

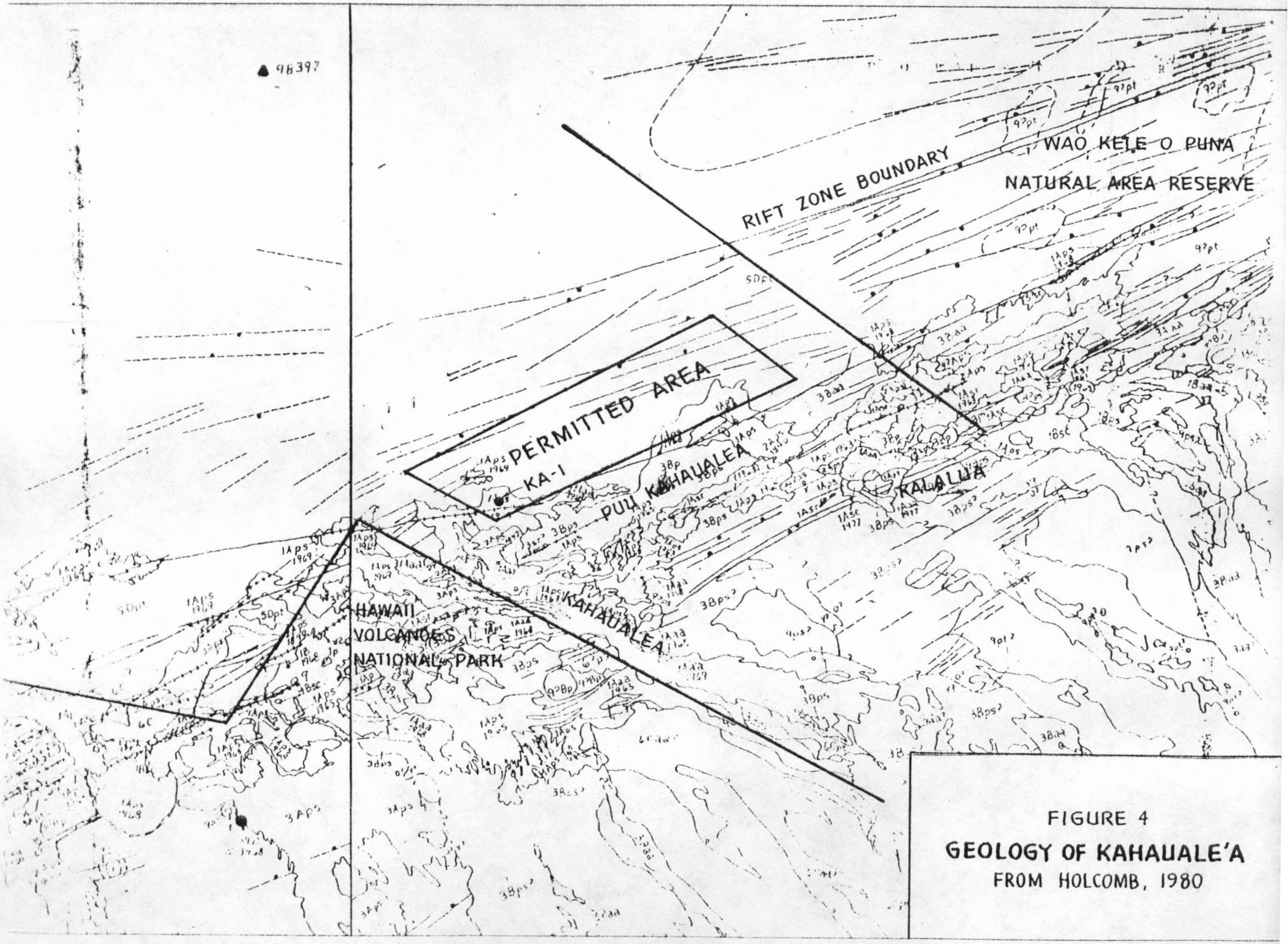


FIGURE 4
GEOLOGY OF KAHAUALE'A
FROM HOLCOMB, 1980

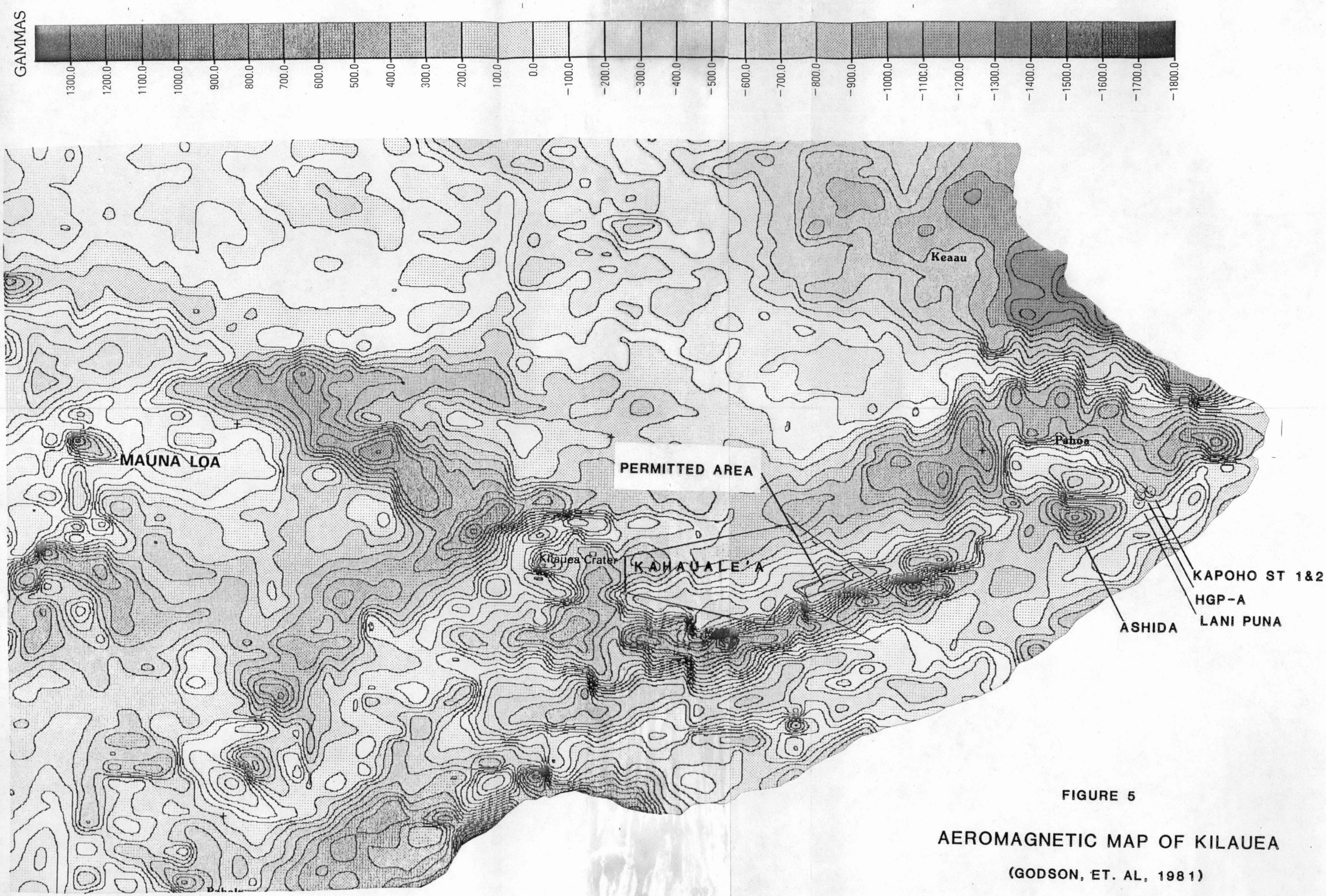


FIGURE 5

AEROMAGNETIC MAP OF KILAUEA

(GODSON, ET. AL, 1981)

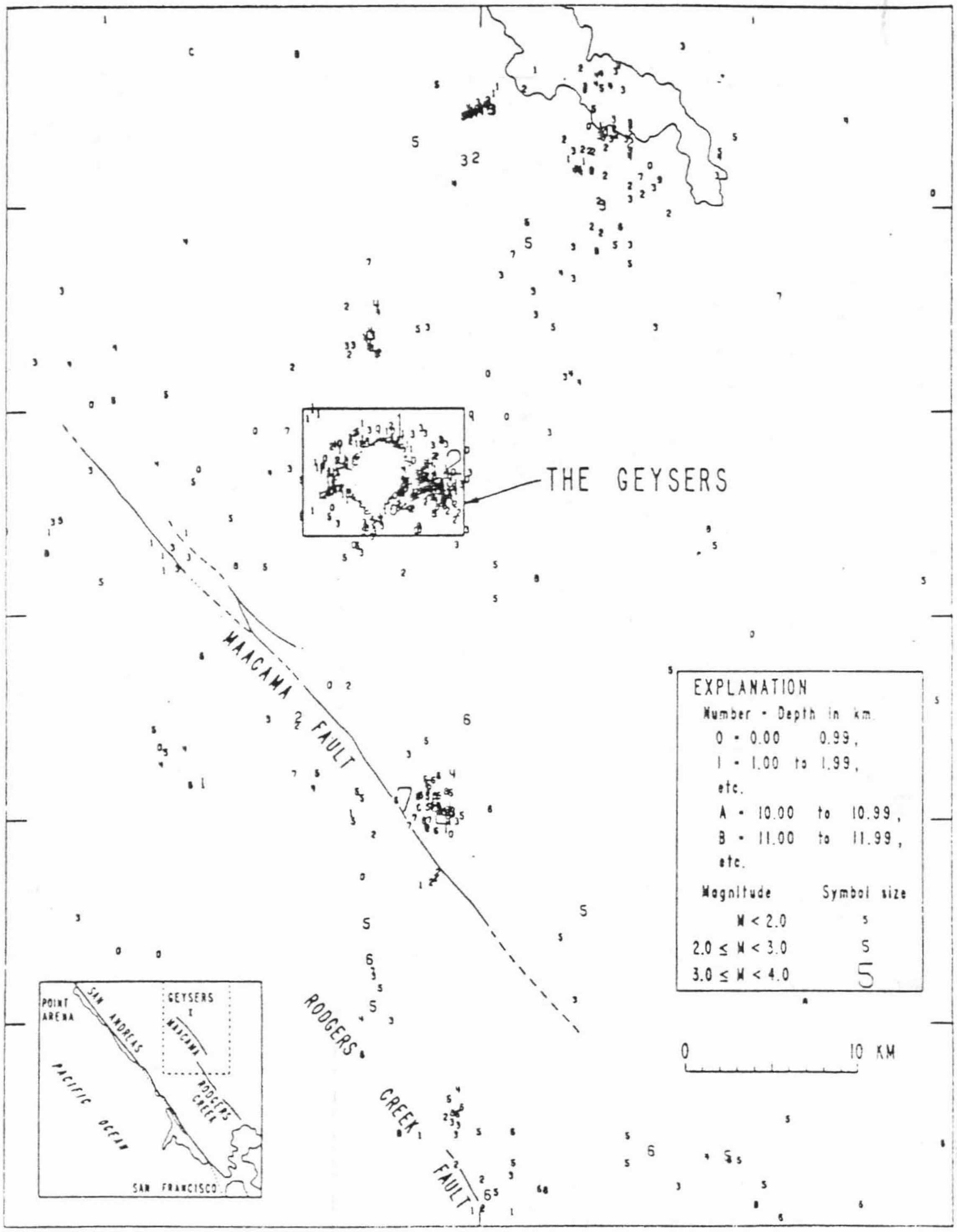


FIGURE 6

GEYSERS MICROEARTHQUAKE MAP

(MARKS, ET AL. 1978)

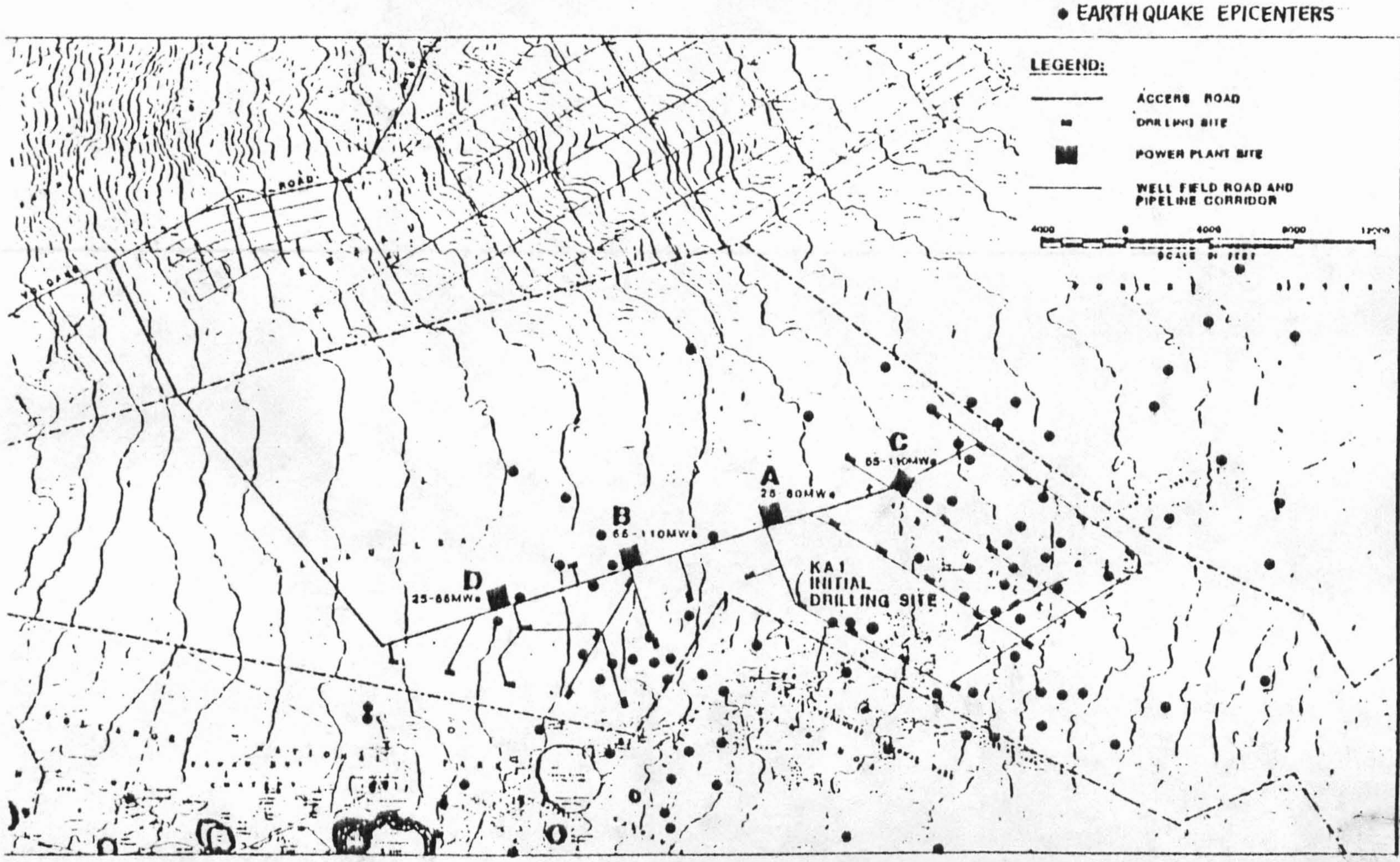


FIGURE 7
EPICENTER MAP
KAHAUALE'A MICROEARTHQUAKE STUDY

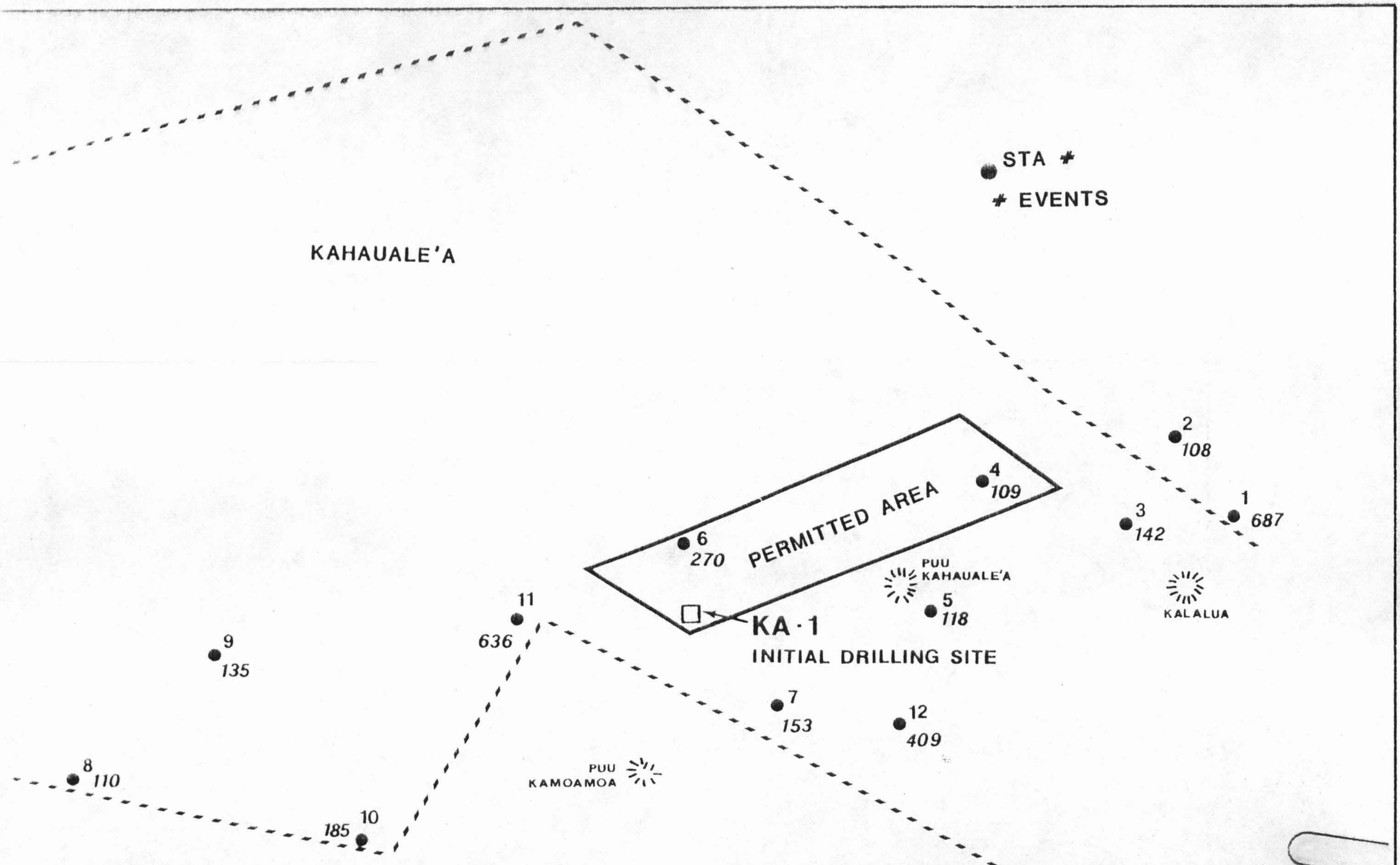


FIGURE 8

EVENTS RECORDED

KAHAUALE'A MICROEARTHQUAKE STUDY

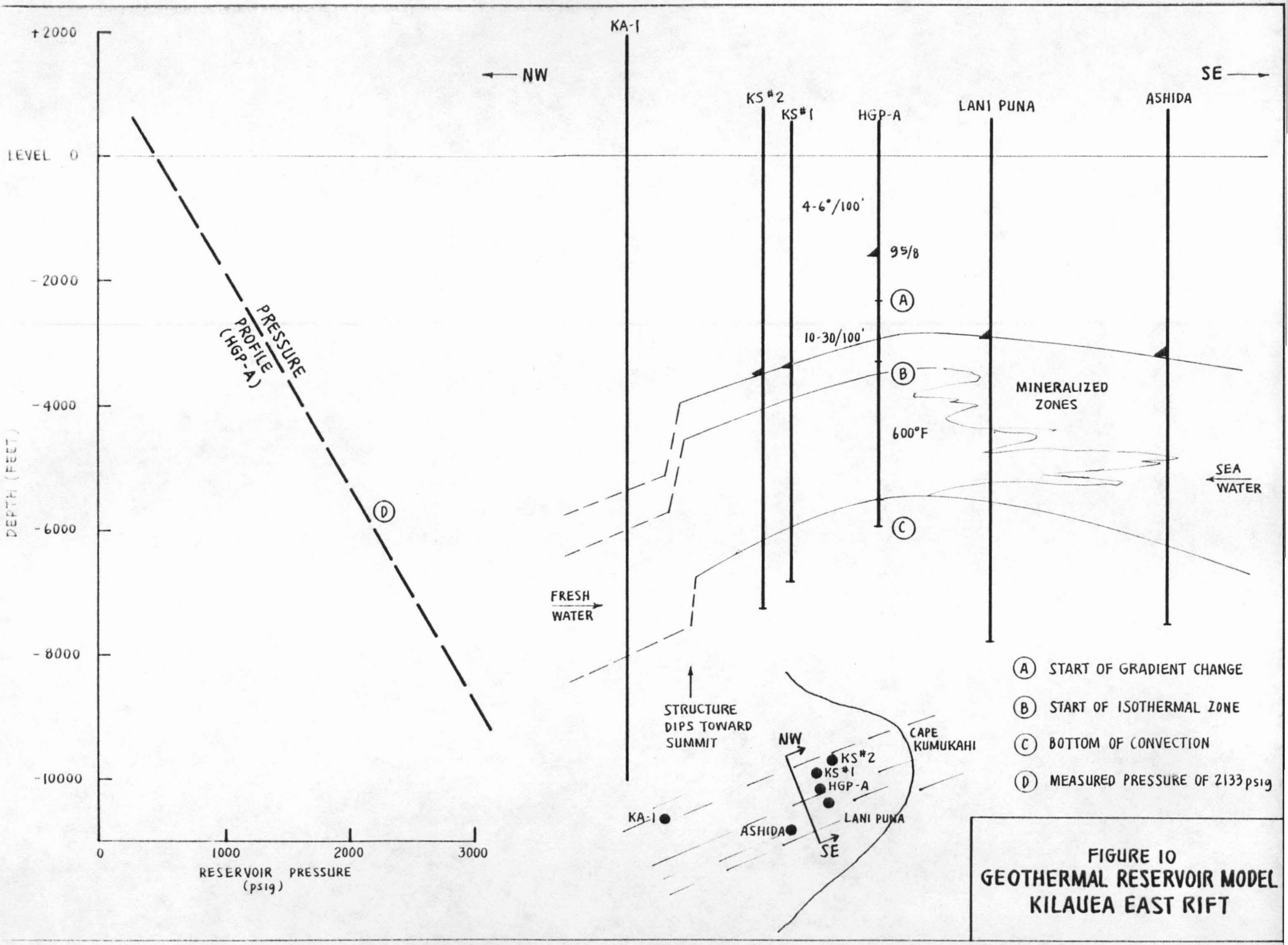


FIGURE 10
GEOTHERMAL RESERVOIR MODEL
KILAUEA EAST RIFT

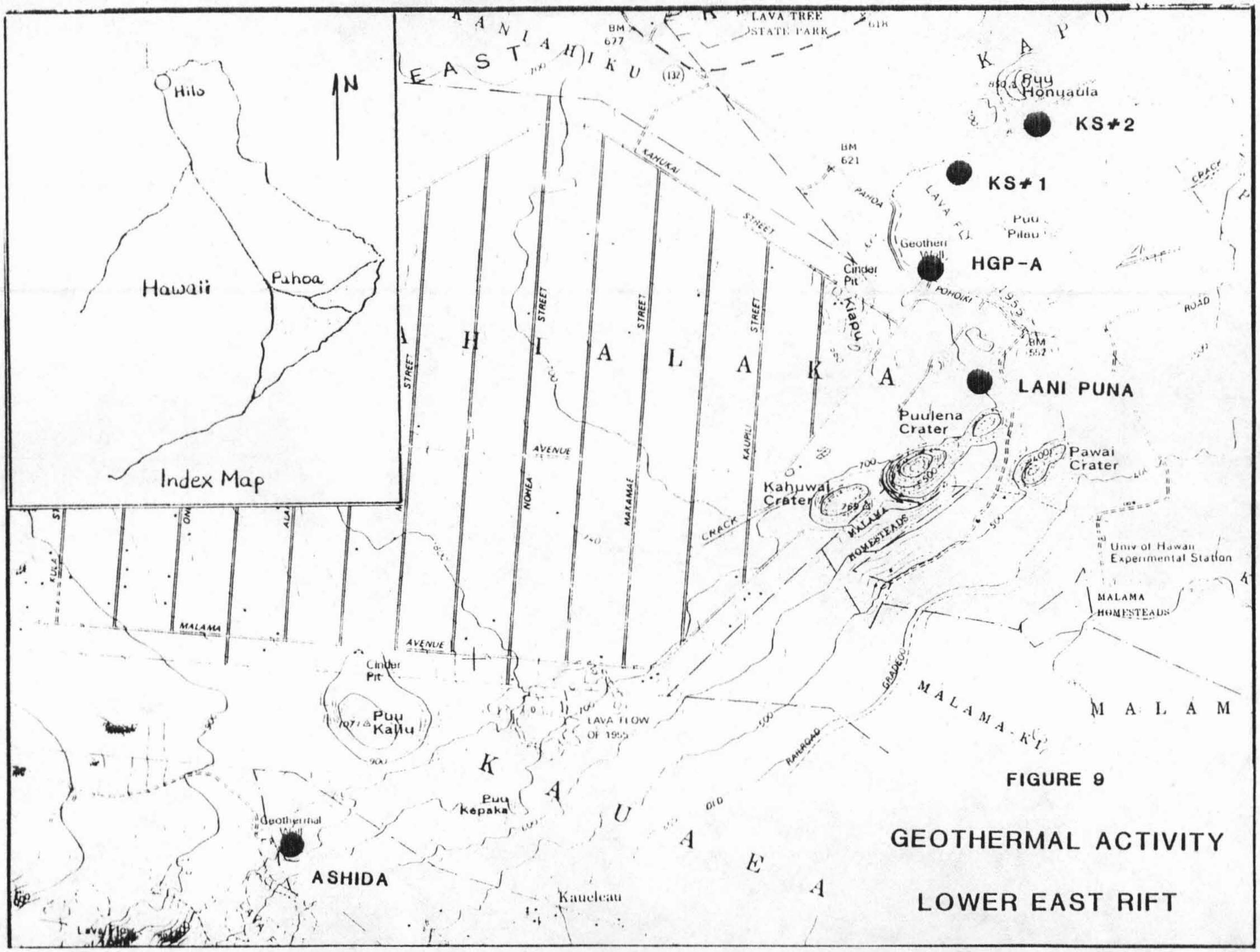


FIGURE 9

GEOTHERMAL ACTIVITY

LOWER EAST RIFT

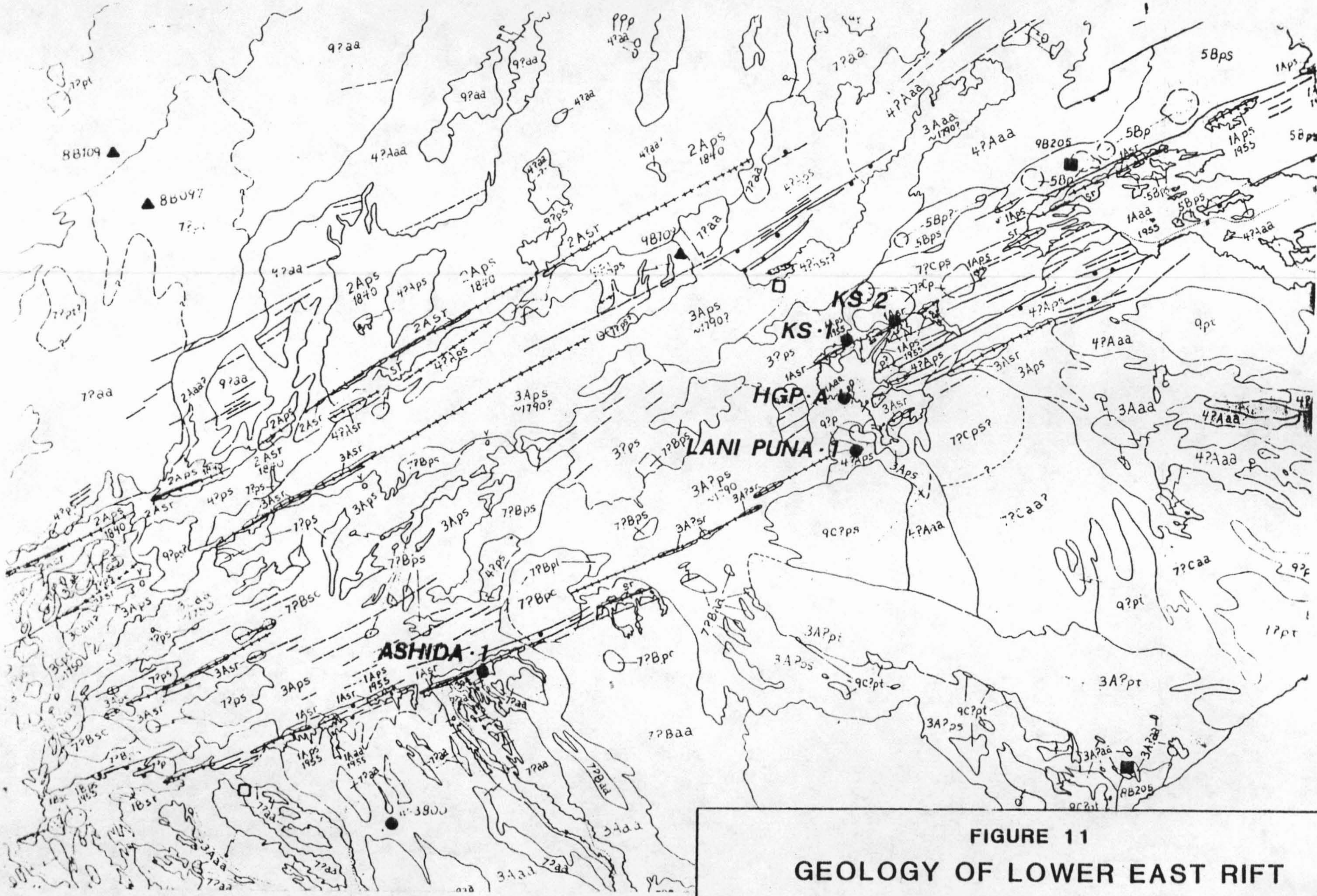


FIGURE 11

GEOLOGY OF LOWER EAST RIFT

(FROM HOLCOMB, 1980)

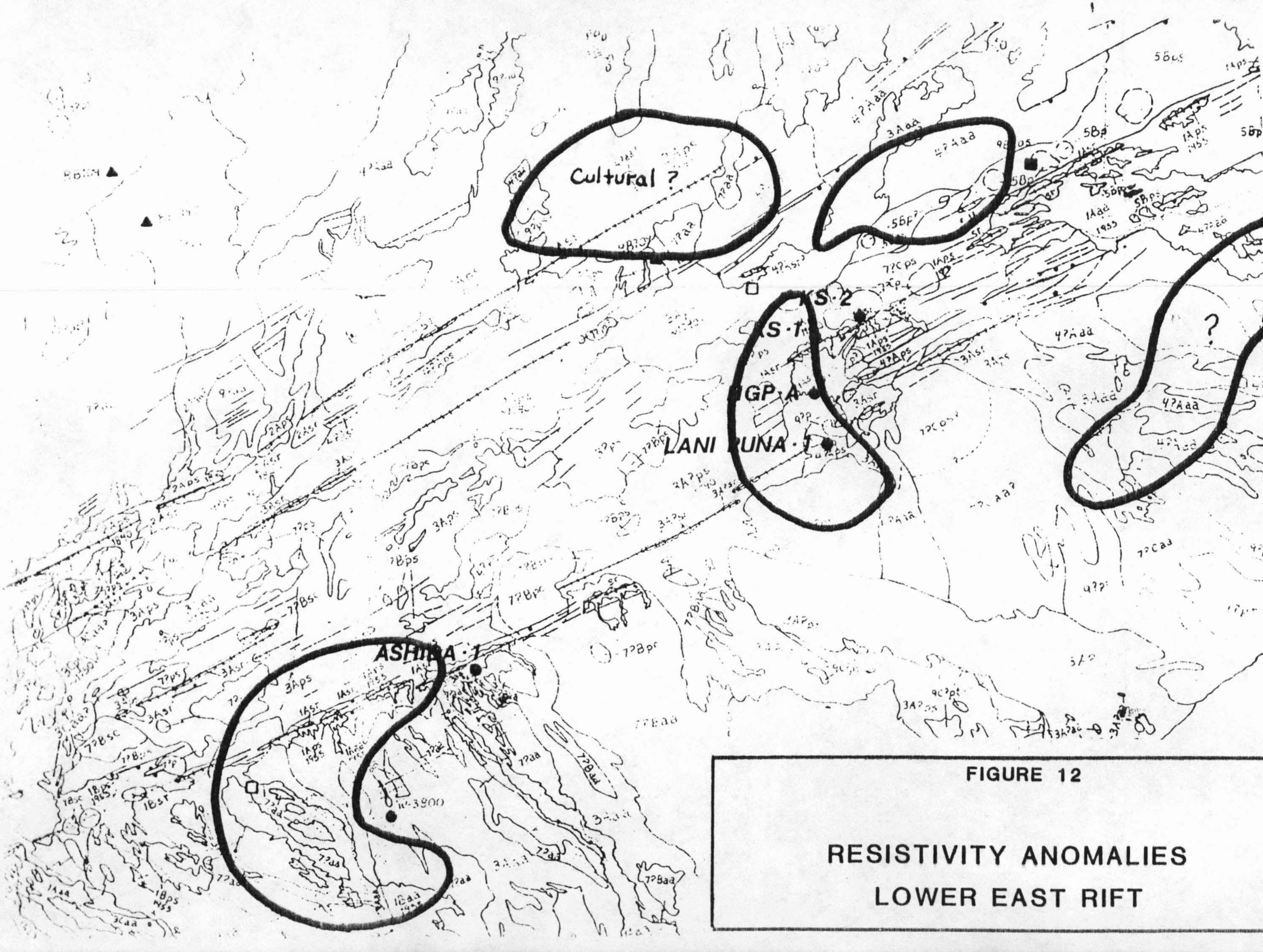


FIGURE 12

RESISTIVITY ANOMALIES
LOWER EAST RIFT

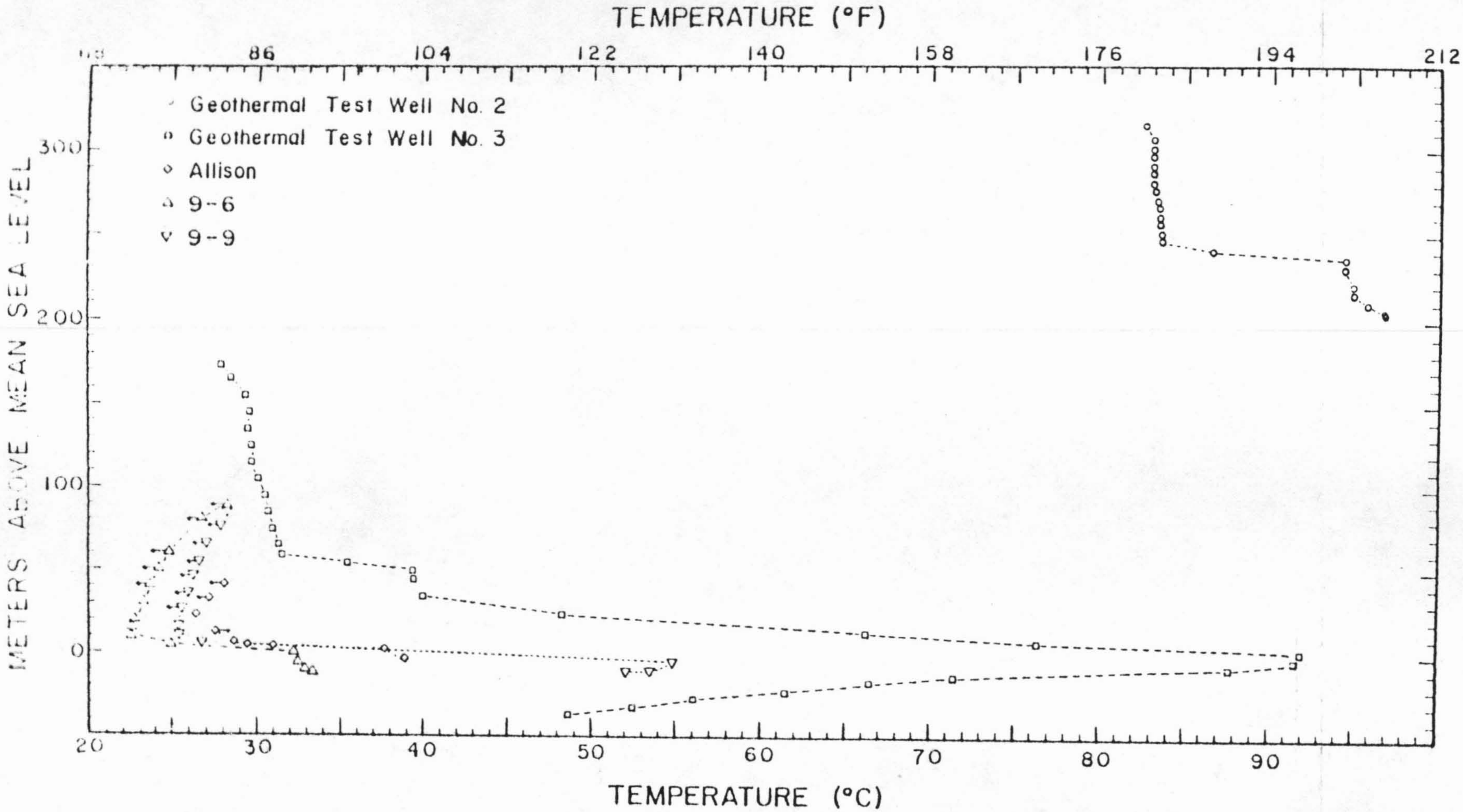


FIGURE 13

TEMPERATURE GRADIENT HOLES

LOWER EAST RIFT

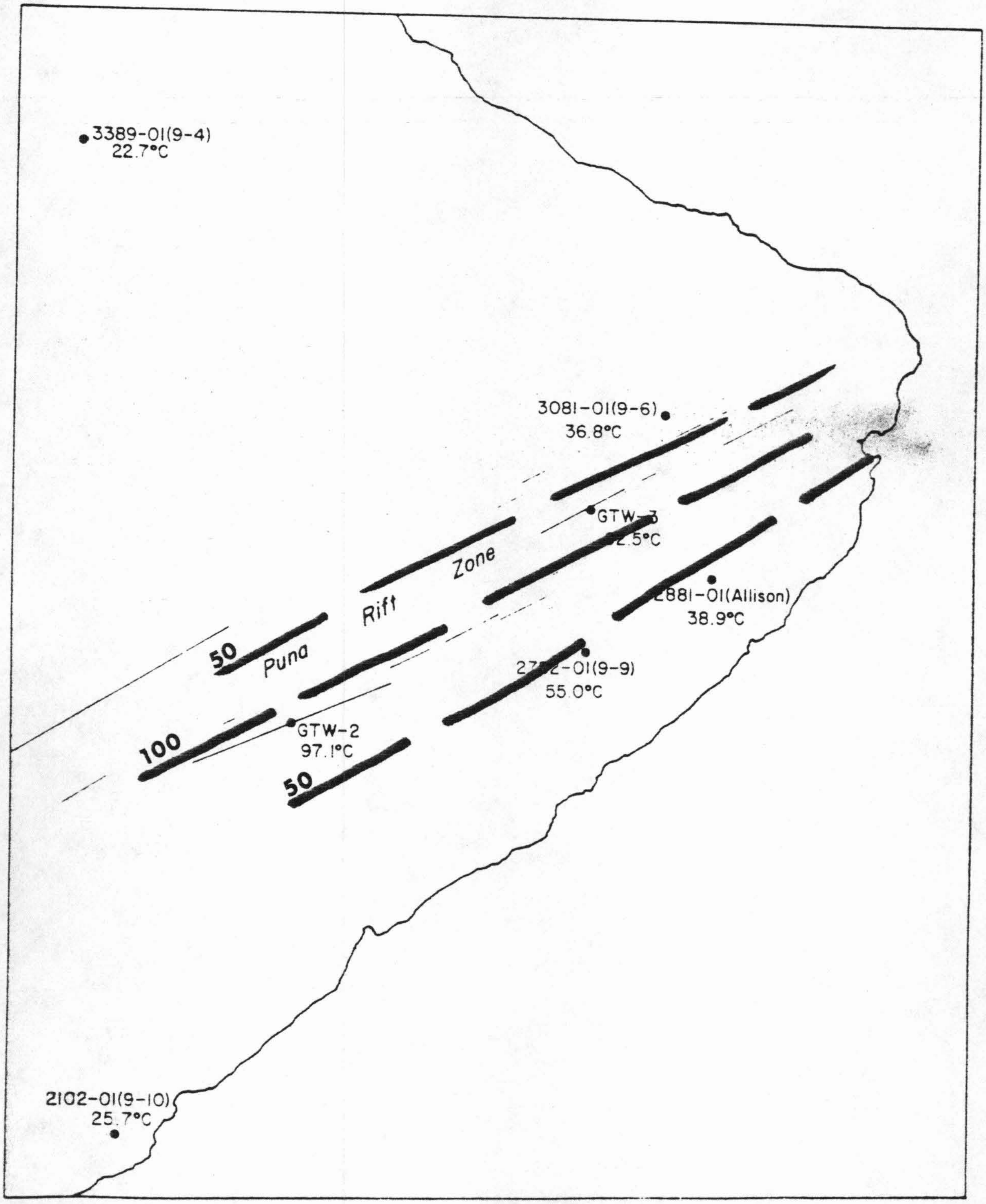


FIGURE 14

TEMPERATURE MAP
LOWER EAST RIFT

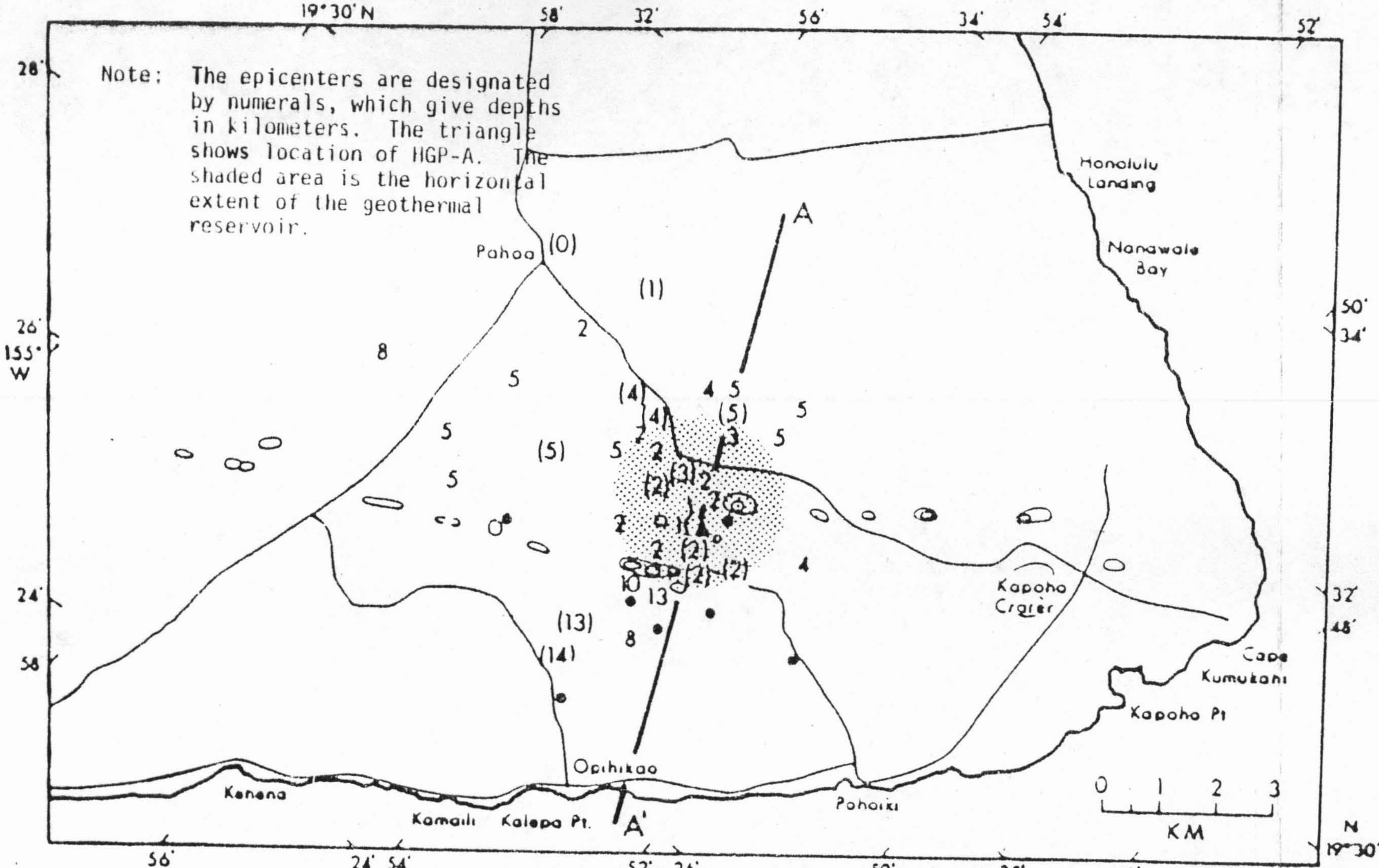


FIGURE 15

EARTHQUAKE EPICENTERS

LOWER EAST RIFT

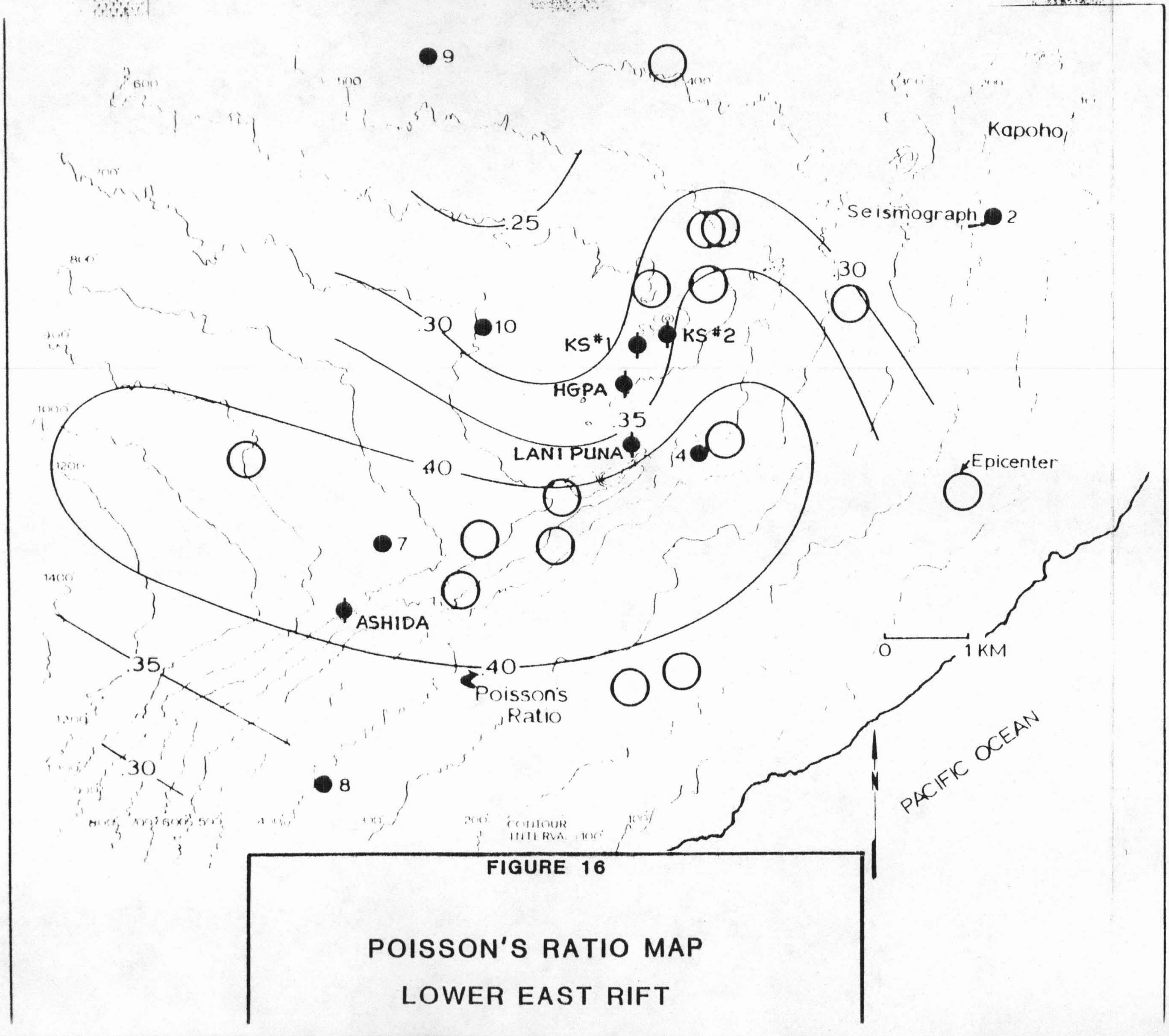


FIGURE 16

POISSON'S RATIO MAP

LOWER EAST RIFT

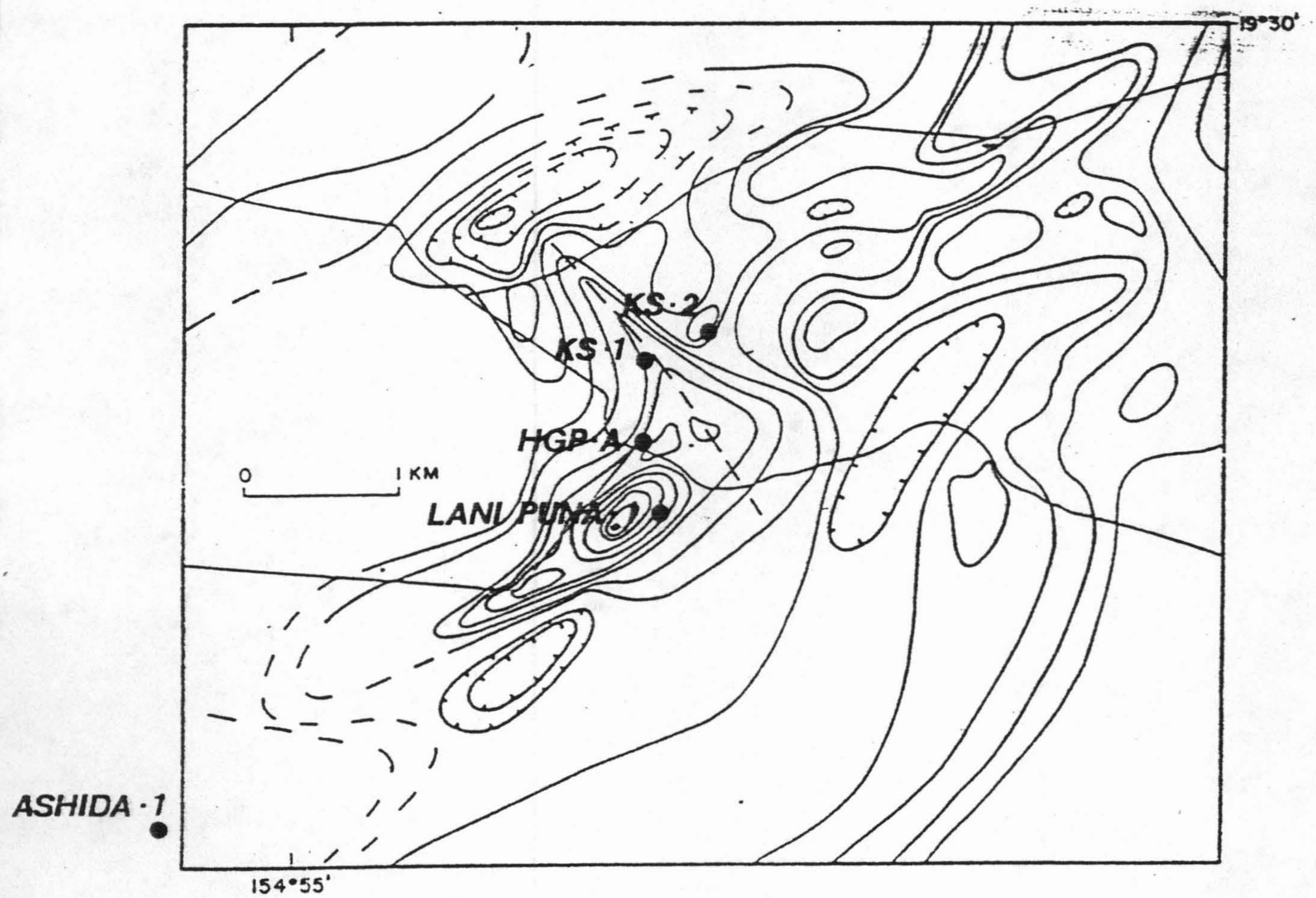


FIGURE 17

SP ANOMALY MAP

LOWER EAST RIFT

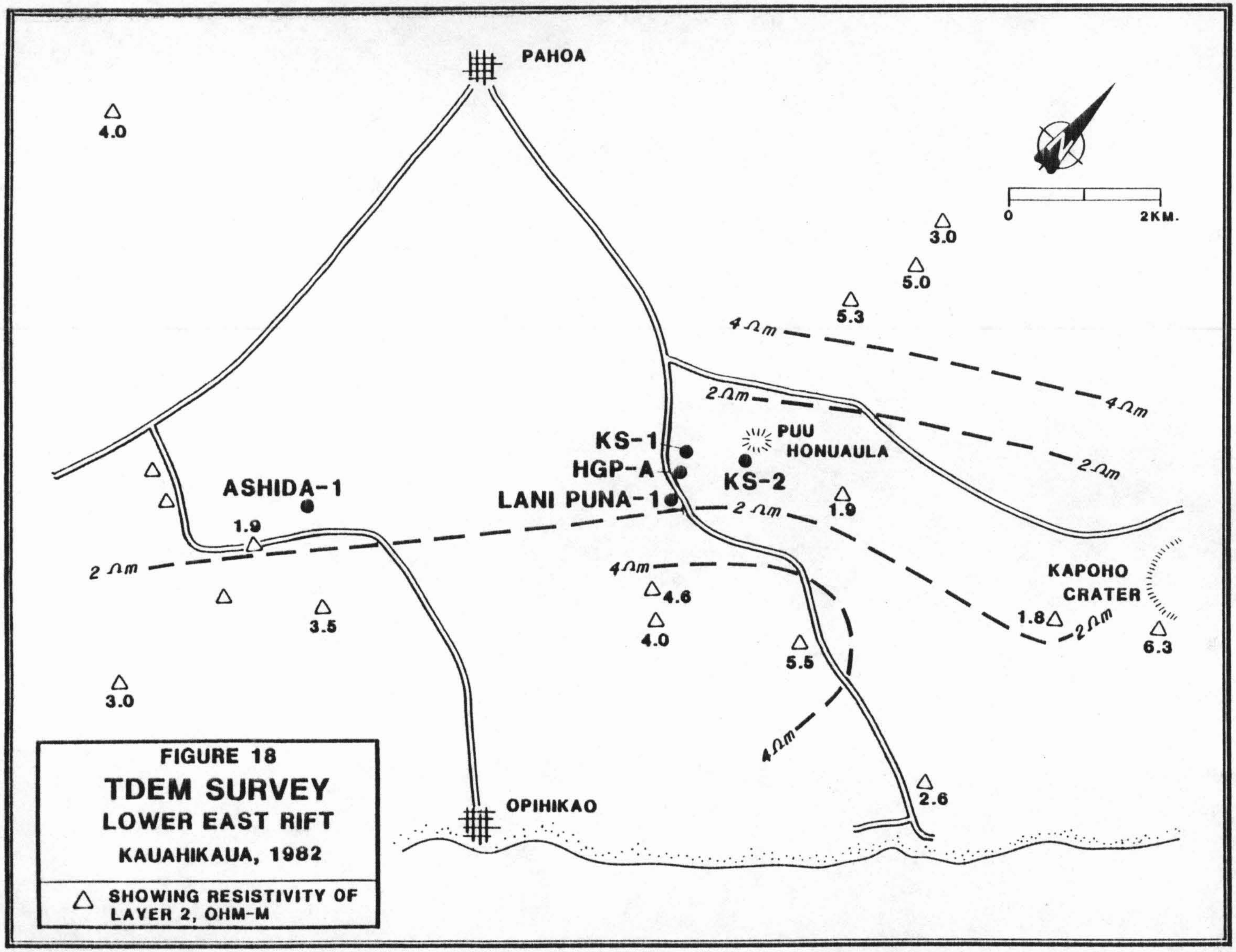
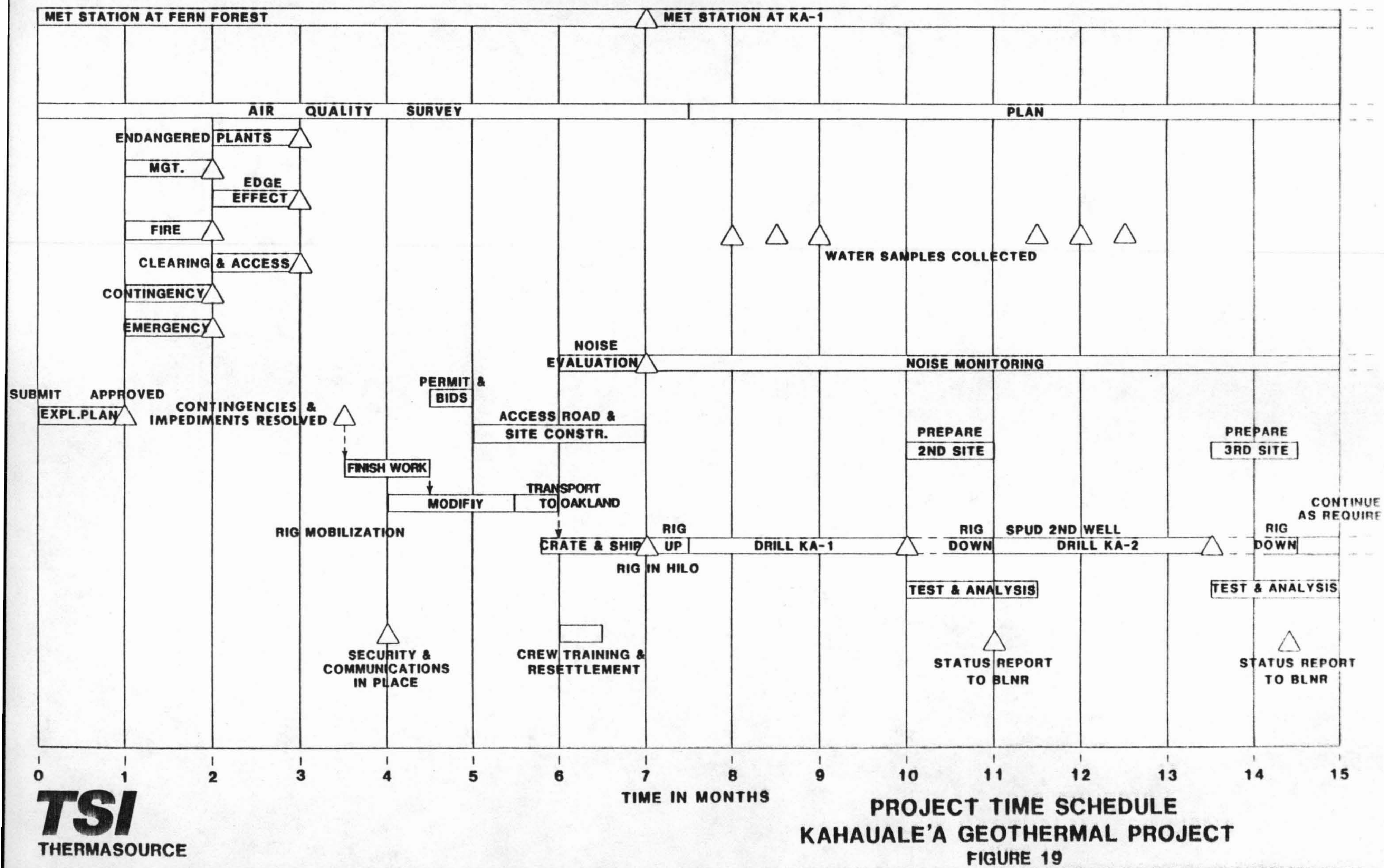
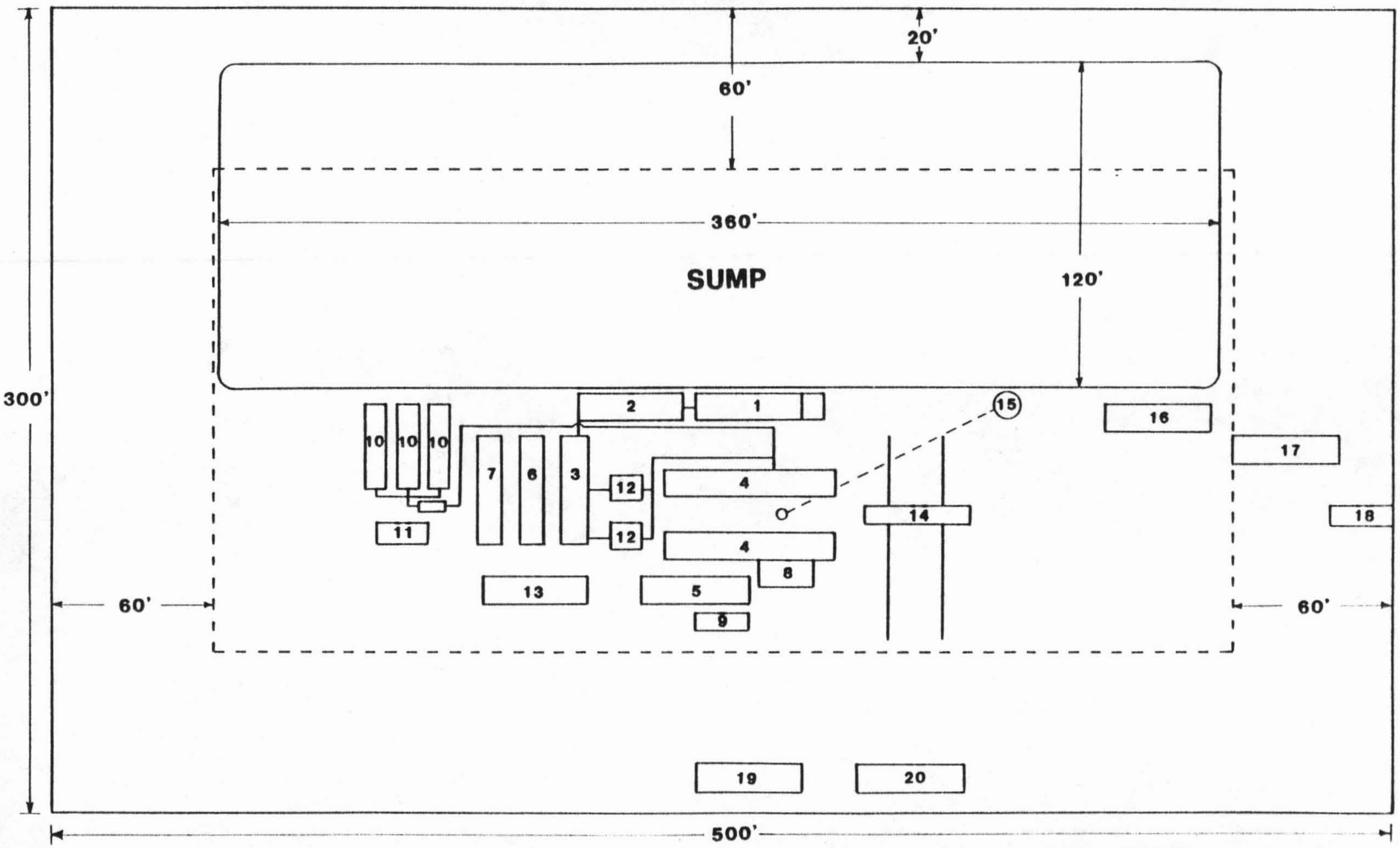


FIGURE 18
TDEM SURVEY
LOWER EAST RIFT
KAUAHIKAUA, 1982

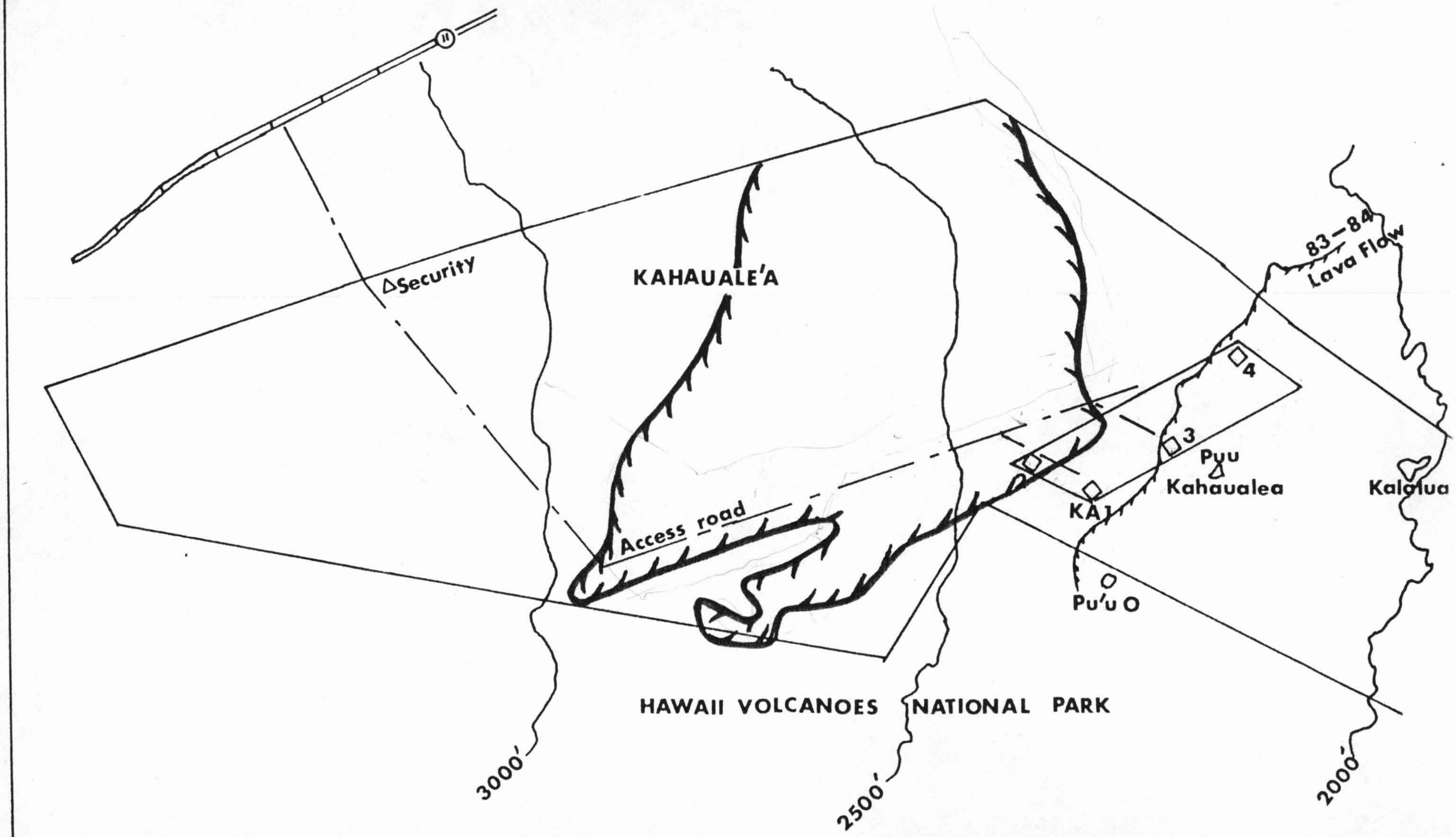


PROJECT TIME SCHEDULE
KAHAUALE'A GEOTHERMAL PROJECT
FIGURE 19



TSI
THERMASOURCE

DRILLING RIG LAYOUT
KAHAUALE'A GEOTHERMAL PROJECT
FIGURE 20



ADENOPHOROUS PERIENS,
10 OR MORE PLANTS PER ACRE

FIGURE 21

EXPLORATION DRILLING SITES

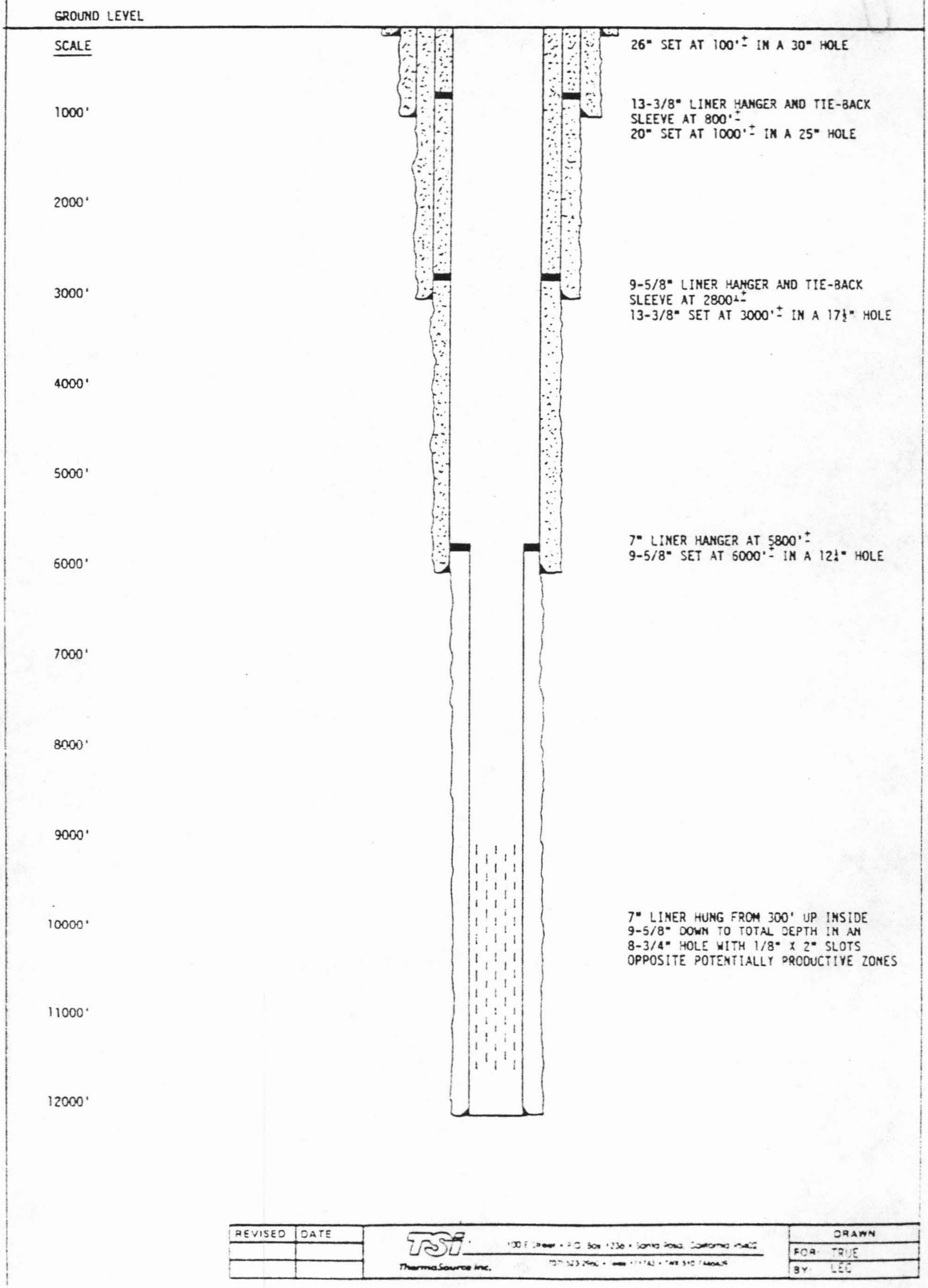


FIGURE 22
WELL SCHEMATIC - KA-1

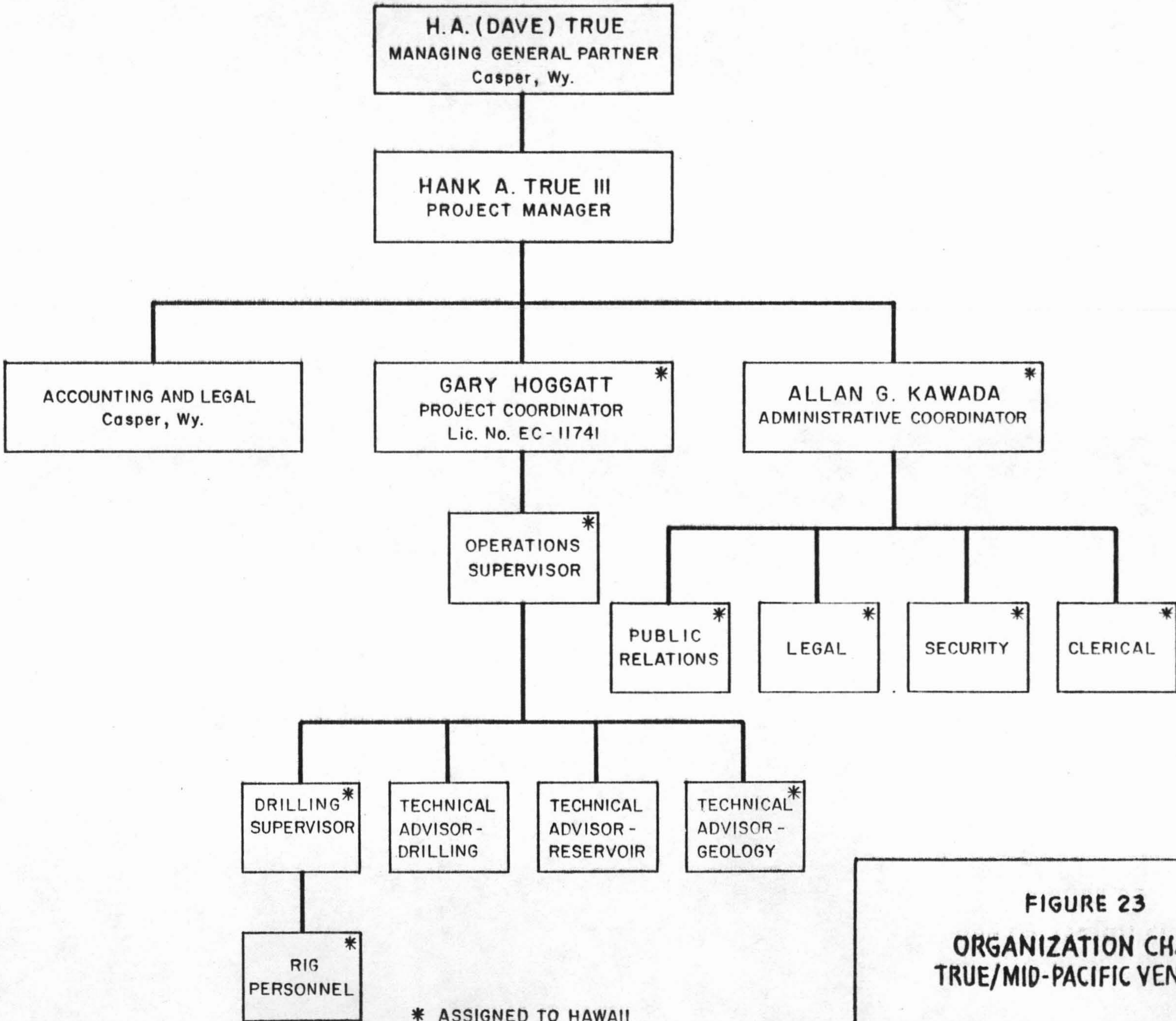
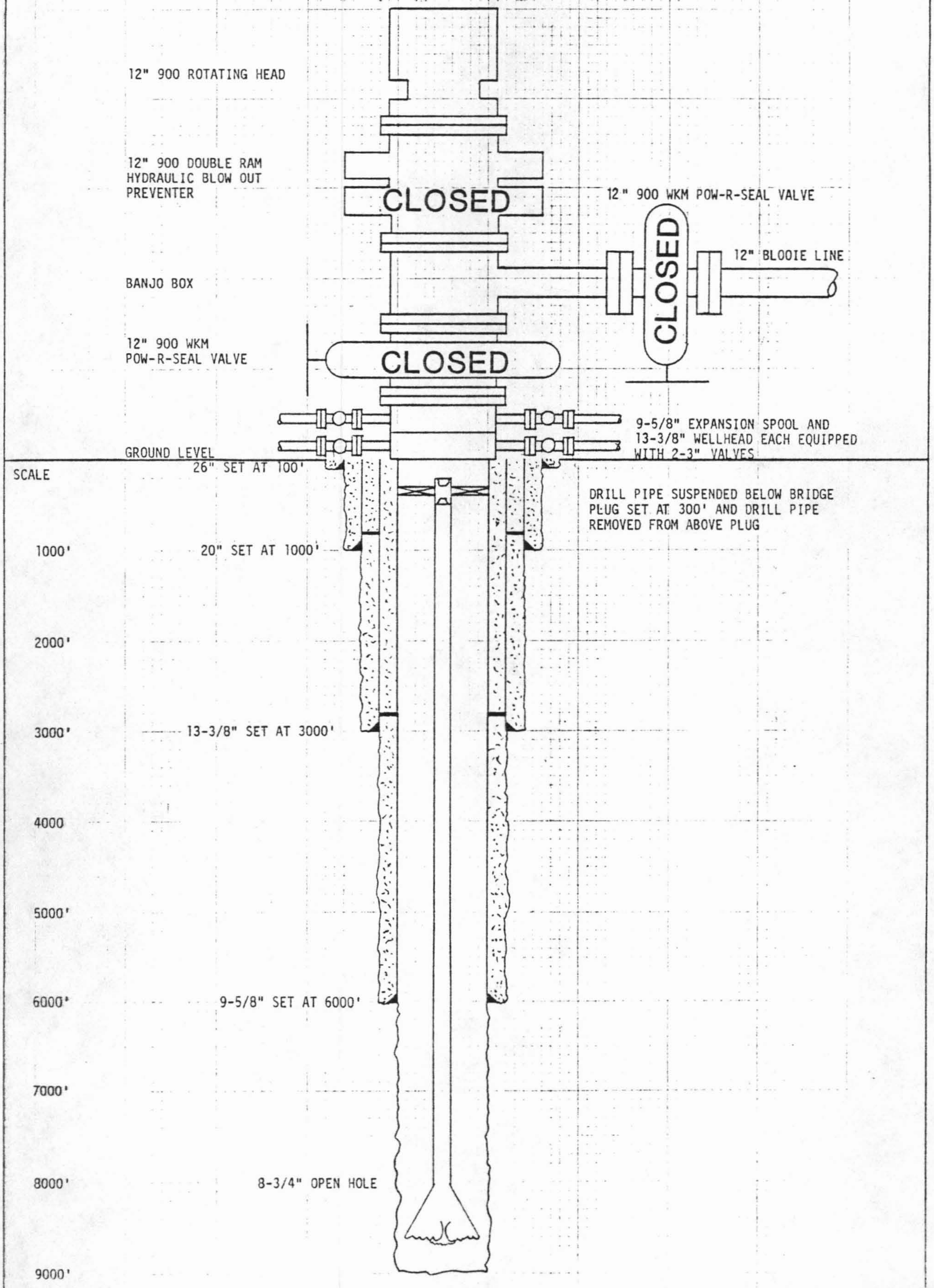


FIGURE 23

ORGANIZATION CHART
TRUE/MID-PACIFIC VENTURE



REVISED	DATE	TSi ThermaSource Inc. 100 E Street • P.O. Box 1236 • Santa Rosa, California 95402 (707) 523-2960 • Telex 171143 • TWX 510 7446439	DRAWN
			FOR: TRUE/MID-PAC.
			BY: LEC
		FIGURE 24	DATE: 2/6/84
			SCALE: N/A

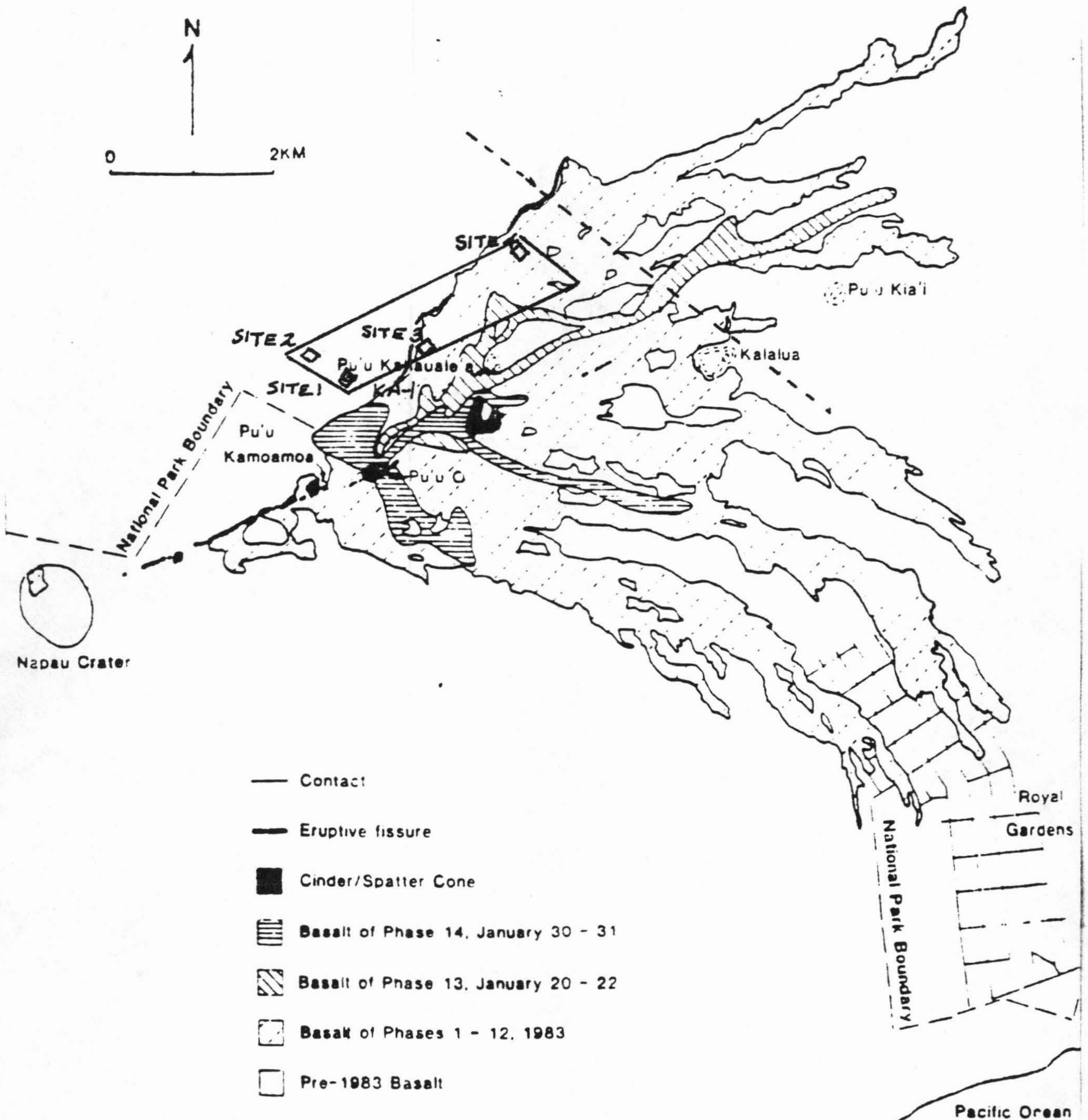


FIGURE 25
1983-1984 KILAUEA EAST RIFT ERUPTION
(FROM HVO REPORT)

Appendix A

KA-1 Drilling Program

Kahauale'a Geothermal Project

ThermaSource Inc.
100 E Street • P.O. Box 1236 • Santa Rosa, California 95402
(707) 523-2960 • Telex 171743 • TWX 510 7446439

TRUE GEOTHERMAL-MID PACIFIC

WELL NO. 1

KAHAULE'A GEOTHERMAL PROJECT

TABLE OF CONTENTS

DRILLING PROGRAM

ThermaSource Inc.
P.O. Box 1236 • Santa Rosa, CA 95402

PREPARED BY	DATE
L.E. Capuano	August 15, 1982

LEASE AND WELL NUMBER	
True Geothermal Well No. 1	
FIELD, COUNTY AND STATE (OR COUNTRY)	**DIVISION**
Campbell Estate, Hilo County, Hawaii	Geothermal
LOCATION	
Kahaule'a Geothermal Project	

DATUM DESCRIP. & ELEVATION	K.B. ABOVE DATUM	PROPOSED TOTAL DEPTH	EST. DRLG. TIME	EST. TOTAL TIME
2500'± above sea level FT.	FT.	12,000'± FT.	55 DAYS	70 DAYS

Sequence of Operations

1. Construct location with 8' x 8' x 6' cellar. Install 36" culvert to serve as conductor. Cement 36" culvert 4 to 5' above cellar floor. Cement floor of cellar and install drain to sump.

2. Rig up rotary drilling rig over center of culvert. Use culvert as a pitcher nipple and flowline.

3. Spud 30" hole and drill to 100'±. Use air hammer if available.

4. Run 26" conductor pipe to total depth. Cement shoe with stab-in assembly through drill pipe. Install cement baskets on 26" casing. See attached 26" Casing Running and Cementing Program for details.

5. Install 26" blow out preventer on conductor as in attached Drawing 007. Test preventer to 100 psi for 15 minutes.

6. Drill out 26" conductor with 25" bit. Use air hammer. Drill 25" hole with air to 1000'±. Take directional survey every 200'. Maintain as straight a hole as possible.

7. Attempt to fill hole with water for logging. Log surface hole as indicated by geologist.

8. Run 20" surface casing to total depth. Cement 20" casing as in attached 20" Casing Running and Cementing Program. See Drawing 002 for details.

9. Install blow out preventers as in attached Drawing 008. Test preventers to 750 psi for 15 minutes.

10. Drill out 20" casing with 17½" bit. Attempt to drill with mud. If unsuccessful, drill with air to 3000'±, 200' below fluid level. Take directional survey every 200'±. Maintain as straight a hole as possible. Maximum deviation to be 5°. Maximum rate of change to be $1\frac{1}{2}^{\circ}$ per 100'.

11. Attempt to fill hole for logging. Log as indicated by geologist. Run multi-shot on conditioning trip before casing.

12. Run 13-3/8" casing as a liner to total depth. Hang 13-3/8" 200'± up inside 20" casing. Cement 13-3/8" liner in one stage. Test and squeeze lap if necessary. Clean out to top of liner and run 13-3/8" tie-back string. Cement tie-back over entire interval. See attached 13-3/8" Liner and Tie-Back Running and Cementing Procedure for details and Drawings 003 and 004.

13. Install blow out preventer system as in attached Drawing 009. Test preventers to 1500 psi for 15 minutes.

DRILLING PROGRAM

ThermaSource Inc.
P.O. Box 1236 • Santa Rosa, CA 95402

PREPARED BY	DATE
L.E. Capuano	August 15, 1982

LEASE AND WELL NUMBER	
True Geothermal Well No. 1	
FIELD, COUNTY AND STATE (OR COUNTRY)	**DIVISION**
Campbell Estate, Hilo County, Hawaii	Geothermal
LOCATION	
Kahaule'a Geothermal Project	

DATUM DESCRIP. & ELEVATION	K.B. ABOVE DATUM	PROPOSED TOTAL DEPTH	EST. DRLG. TIME	EST. TOTAL TIME
2500'± above sea level FT.	FT.	12,000'± FT.	55 DAYS	70 DAYS

Page 2:

14. Drill out cement from bottom of tie-back. Retest casing to 1500 psi.

15. Condition fluid in hole to mud. Drill out all cement from 13-3/8" casing.

16. Drill ahead with 12¼" bit to reservoir temperature, approximately 6000'±. Take directional survey every 200'. Maintain as straight a hole as possible. Maximum deviation to be 8°. Maximum rate of change to be 1½° per 100'.

17. Run logs as indicated by geologist. Run multi-shot survey on condition trip before casing.

18. Run 9-5/8" casing as a liner to total depth. Hang 9-5/8" 200'- up inside 13-3/8" casing. Cement 9-5/8" liner in one or two stages as indicated from circulating conditions. Test and squeeze lap is necessary. Clean out to top of liner and run 9-5/8" tie-back string. Cement tie-back over entire interval. See attached 9-5/8" Liner and Tie-Back Running and Cementing Program for details, and Drawings 005 and 006.

19. Install 9-5/8" expansion spool and blow out preventers as in attached Drawing 010. Test preventers to 1500 psi for 15 minutes.

20. Drill out cement from bottom of tie-back. Retest casing to 1500 psi.

21. Drill out all cement with mud. Convert system to water.

22. Blow out water with air and drill ahead with 8-3/4" bit to total depth or commercial production.

23. Test well on short term (8 hours). Shut well in and run in hole with bit to check for fil

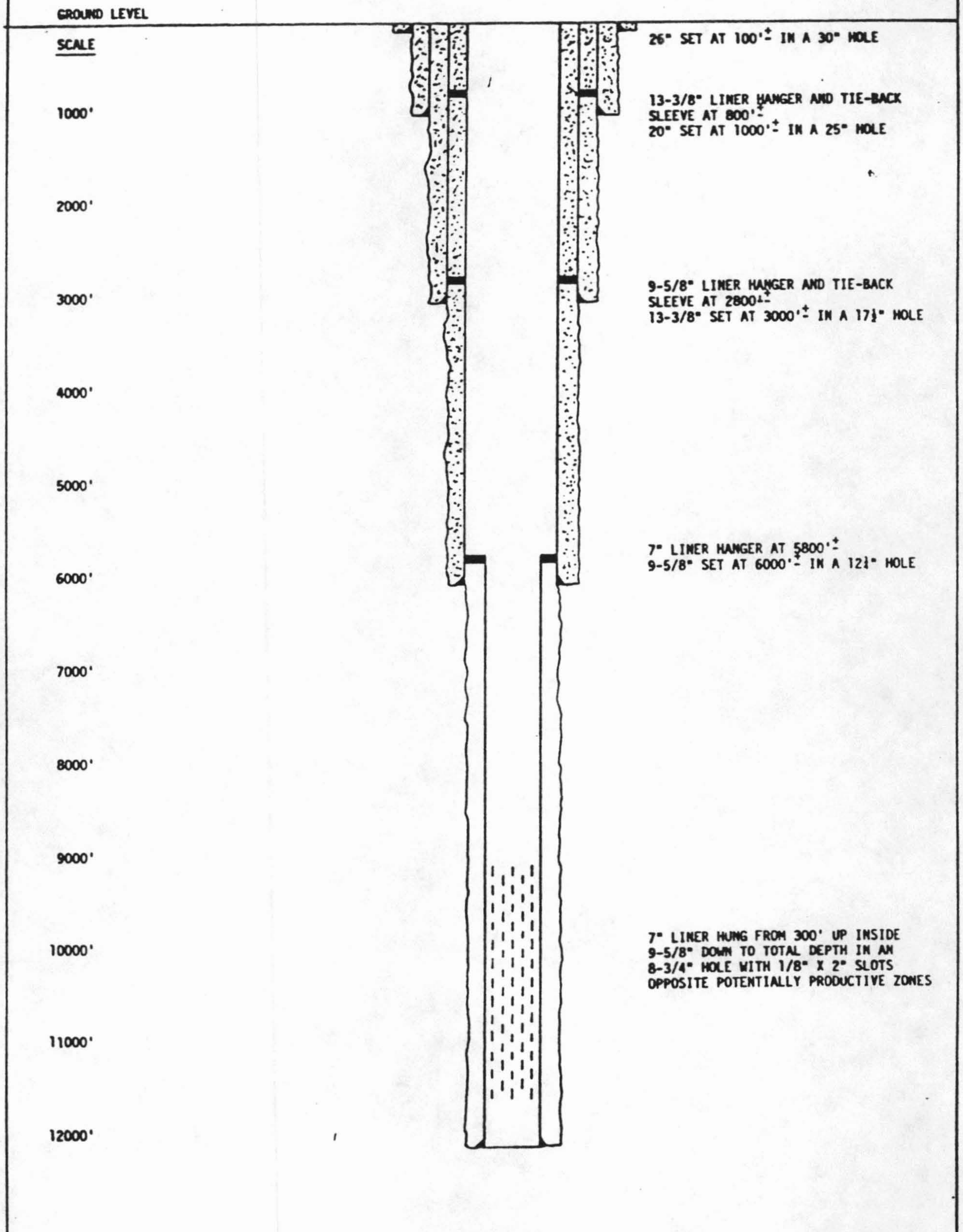
24. Run 7" slotted liner if indicated from bit run. See Drawing 001.

25. Retest well on short term (8 hours).

26. Run logs, pressure and temperature surveys.

27. Run in hole and pull out, laying down drill pipe. Release rig.

28. Perform long term test with mufflers and separators.



REVISED	DATE

TSi ThermaSource Inc.
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(707) 523 2960 • Telex 171743 • TWX 510 7446439

WELL COMPLETION DIAGRAM
TRUE GEOTHERMAL
HAWAII PROJECT

DRAWN	
FOR:	TRUE
BY:	LEC
DATE:	8/15/82
SCALE:	1"=1000' Vert.
DRAWING No.	001

ThermaSource Inc.
P.O. Box 1236 • Santa Rosa, CA 95402

MUD, LOGGING, WELLHEAD & DIRECTIONAL PROGRAMS

WELL: True No. 1

MUD

DEPTH INTERVAL	MUD TYPE	WEIGHT	API FLUID LOSS	YIELD POINT	PH	
0 - 100'	Gel and Water	65#/ft.^{3}	---	15	9.0	
100 - 1000'	Gel and Water or Air*	70#/ft.^{3}	10 cc	15	9.0	
1000' - 3000'	Gel and Water or Air*	70#/ft.^{3}	10 cc	15	10.0	
3000 - 6000'	Gel and Water or Air*	70#/ft.^{3}	3.2 cc	15	10.0	
6000 - T.D.	Water or Air*	65#/ft.^{3}	or 3000 cfm			

REMARKS

* If unable to maintain circulation due to lost circulation, first attempt to aerate system, then attempt to drill with air with rotary bit or air hammer (see attached). If misting is required, it may be necessary to increase air volume 30%. Misting mix should be fresh water mixed with 2-6 gal/10 bbls of Magcobar Foamer. Maintain a solution pH above 10.0 to inhibit corrosion. Use unisteam as outlined in special considerations.

LOGGING

DEPTH INTERVAL	LOG TYPES	LOG SCALES
100 - 1000'	Temperature log & logs as directed	1" and 5" = 100'
1000 - 3000'	" " " "	" "
3000 - 6000'	" " " "	" "
6000 - T.D.	" " " "	" "
0 - T.D.	Samples every 10'	

REMARKS

All logs to be determined by geologist.

WELLHEAD

API NOMINAL SIZE	WORKING PRESSURE PSI	TYPE	MAKE
26"	100 psi	Single ram type or hydril	
20" x 20"	750 psi	*	Rental
13-3/8" x 12"	1500 psi	13-3/8" SOW x 12" 900 API with 12¼" bore and 2-3 2000 psi outlets.	WKM
12" x 10"	1500 psi	12" 900 x 10" 900 expansion spool with 10" bore and 2-3 200 psi outlets.	WKM
10" x 10"	1500 psi	10" 900 Pow-R-Seal valve	WKM

REMARKS

* 20" 600 API x 20" 600 API with 2 outlets weld-on flange will due.

DIRECTIONAL OR STRAIGHT-HOLE

Drill hole as straight as possible, taking directional shots every 200'± from 0-6000' and on dull bits after 6000'. 0-3000' maximum deviation to be 5°, maximum rate of change to be 1½° per 100'. 3000-6000' maximum deviation to be 8°, maximum rate of change to be 1½° per 100'. 6000'-T.D. monitor without control.

ThermaSource Inc.
P.O. Box 1236 • Santa Rosa, CA 95402

CASING, CEMENTING AND BOP PROGRAMS

CASING PROGRAM

SIZE	DEPTH		WELL
26"	100' ±	Conductor	True No. 1

INTERVAL	WEIGHT LB/FT	GRADE	JOINT TYPE	CALCULATED SAFETY FACTORS: TOP BURST	BOT. BURST	COLL.	TENSION
0 - 100' ±	3/8" WALL.		PLAIN END				

DESIGN CONDITIONS

SURFACE BURST PRESSURE - PSI	OUTSIDE MUD WT. (COLLAPSE) - PPG
INSIDE MUD WEIGHT (BURST) - PPG	INSIDE MUD WT. (COLLAPSE) - PPG
OUTSIDE MUD WEIGHT (BURST) - PPG	FORM. PRESS. GRAD. AT SHOE (COLLAPSE) - PPG
FRAC. GRAD. AT SHOE (BURST) - PPG	BIAXIAL LOAD: COLL. ☐ BURST ☐ BOUYANCY: YES ☐ NO ☐

CEMENTING PROGRAM

SLURRY DESCRIPTION AND PROPERTIES

SLURRY DESCRIPTION (AND NUMBER)

250 cu. ft. (218 sacks) of class G cement blended with 3% $CaCl_2$.

DESIRED TOP	EXCESS
Surface	100%

SLURRY VOL. - CU FT / (SLURRY NO.)	250			
SLURRY YIELD - CUBIC FEET/SACK	1.15			
SLURRY DENSITY - [redacted] #/cu. ft.	118			
THICKENING TIME - DEPTH SCH/HRS. MIN.	4 hours ±			
COMPRESSIVE STRENGTH - PSI/HOURS	1870 psi @ 100°F in 8 hours.		3885 psi @ 100°F in 24 hours.	

RUNNING AND CEMENTING INSTRUCTIONS

SHOE, COLLAR(S) AND JOINT STRENGTHENING

1. Weld-on float collar located 10' from bottom.
2. All joints should be welded.
3. Set casing on bottom. Put cement ports in pipe, 1', 2', and 3' up.

CENTRALIZERS AND SCRATCHERS - NUMBER, TYPE AND SPACING

1. No centralizers.
2. Run one cement basket 10' up from bottom.
3. Run one cement basket 50' up from bottom and one 15' below surface.

PREFLUSH, DISPLACEMENT RATE, PLUGS, RECIPROCATION, ETC.

1. Stab into float collar with drill pipe.
2. Attempt to pump water around.
3. Pump 200 cu. ft. $CaCl_2$ water, 100 cu. ft. fresh water, 200 cu. ft. Flo-Chek ahead of cement followed by Geo-gel then 100 cu. ft. cement.

PRESSURE TESTING AND LANDING

1. Fill annulus from surface with ready mix concert until cement comes up to bottom of cellar.
2. Wait on cement six hours before landing and cutting off casing for blow out preventers.

BOP PROGRAM

API STACK ARRANGEMENT CODE	WORKING PRESSURE PSI	MINIMUM BORE INCHES	TYPE	TEST PRESSURES - PSI: RAM TYPE	ANNULAR TYPE	ROTATING HEAD
	1000 psi	25"	See Drawing 007	---	100 psi	----

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CASING, CEMENTING AND BOP PROGRAMS

CASING PROGRAM

SIZE	DEPTH		WELL
20"	1000'±	Surface	True No. 1

INTERVAL	WEIGHT LB/FT	GRADE	JOINT TYPE	CALCULATED SAFETY FACTORS: TOP BURST	BOT. BURST	COLL.	TENSION
0 - 1000'±	106ppf	K-55	Butress	3.31	9.21	1.64	9.99

DESIGN CONDITIONS

SURFACE BURST PRESSURE -	750	PSI	OUTSIDE MUD WT. (COLLAPSE) -	9.0	PPG
INSIDE MUD WEIGHT (BURST) -	13.0	PPG	INSIDE MUD WT. (COLLAPSE) -	0	PPG
OUTSIDE MUD WEIGHT (BURST) -	9.0	PPG	FORM. PRESS. GRAD. AT SHOE (COLLAPSE) -		PPG
FRAC. GRAD. AT SHOE (BURST) -	14.0	PPG	BIAXIAL LOAD: COLL. [X] BURST [X]	BOUYANCY: YES [ ] NO [X]	

CEMENTING PROGRAM

SLURRY DESCRIPTION AND PROPERTIES

SLURRY DESCRIPTION (AND NUMBER)

2152 cu. ft. (624 sacks) class G cement blended with 50#/sack of spherelite cement, 40% silica flour, 5% hydrated lime, 4% gel, 1% CFR-2 and 0.5% Halad-22A, tailed with 300 cu. ft. (261 sacks) class G cement blended with 3% $CaCl_2$.

DESIRED TOP: Surface | EXCESS: 100%

SLURRY VOL. - CU FT / (SLURRY NO.)	2152	300		
SLURRY YIELD - CUBIC FEET/SACK	3.45	1.15		
SLURRY DENSITY - [redacted] #/cu. ft.	82	118		
THICKENING TIME - DEPTH SCH/HRS. MIN.	4 hours	4 hours		
COMPRESSIVE STRENGTH - PSI/HOURS				

RUNNING AND CEMENTING INSTRUCTIONS

SHOE, COLLAR(S) AND JOINT STRENGTHENING

1. Stab in type float collar loacted 40' up from bottom. Guide shoe on bottom.
2. Weld bottom of collars on bottom 4 joints.
3. Clean and Bakerloc threads on bottom 4 joints.
4. Tac-weld top of collars on last 2 joints.

CENTRALIZERS AND SCRATCHERS - NUMBER, TYPE AND SPACING

1. Run centralizer in middle of bottom two joints, then one every other tool joint on entire string except top 100'.
2. Put centralizer cement baskets in middle of bottom 2 joints, one at 500' down, one at 120', and 90' down from surface.

PREFLUSH, DISPLACEMENT RATE, PLUGS, RECIPROCATION, ETC.

1. Stab into float collar with drill pipe. Attempt to circulate with water.
2. Pump 200 cu. ft. $CaCl_2$ water followed by 100 cu. ft. fresh water, 200 cu. ft. Flo-Chek, 200 cu. ft. Geo-gel, then cement slurries.
3. See attached detail.

PRESSURE TESTING AND LANDING

1. Use 1" pipe in annulus of 20" and 26" to bring cement back to surface if necessary.
2. Wait on cement six hours.

BOP PROGRAM

API STACK ARRANGEMENT CODE	WORKING PRESSURE PSI	MINIMUM BORE INCHES	TYPE	TEST PRESSURES - PSI: RAM TYPE	ANNULAR TYPE	ROTATING HEAD
	1000 psi	20"	See Drawing 008	750 psi	750 psi	----

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20" CASING CEMENTING PROCEDURE

1. Run 20" casing into hole with stab-in type cementing float 80' above guide shoe on bottom.

2. Place a cement basket type centralizer in the middle of the bottom two joints. Place one 500' down and one just inside and one just outside the bottom of the 26" casing.

3. Run in hole with drill pipe and stab into float. Pump enough water to fill drill pipe and 20" x 25" annulus two times. If no circulation, proceed with cementing. See Drawing 002. Tie down casing prior to cementing.

4. Pump 200 cu. ft. $CaCl_2$ water and 100 cu. ft. fresh water, followed by 200 cu. ft. Halliburton Flo-Chek, 200 cu. ft. Geo-gel flush, then cement slurries for Stage 1.

5. If lead cements start coming out of annulus, immediately switch to tail slurry.

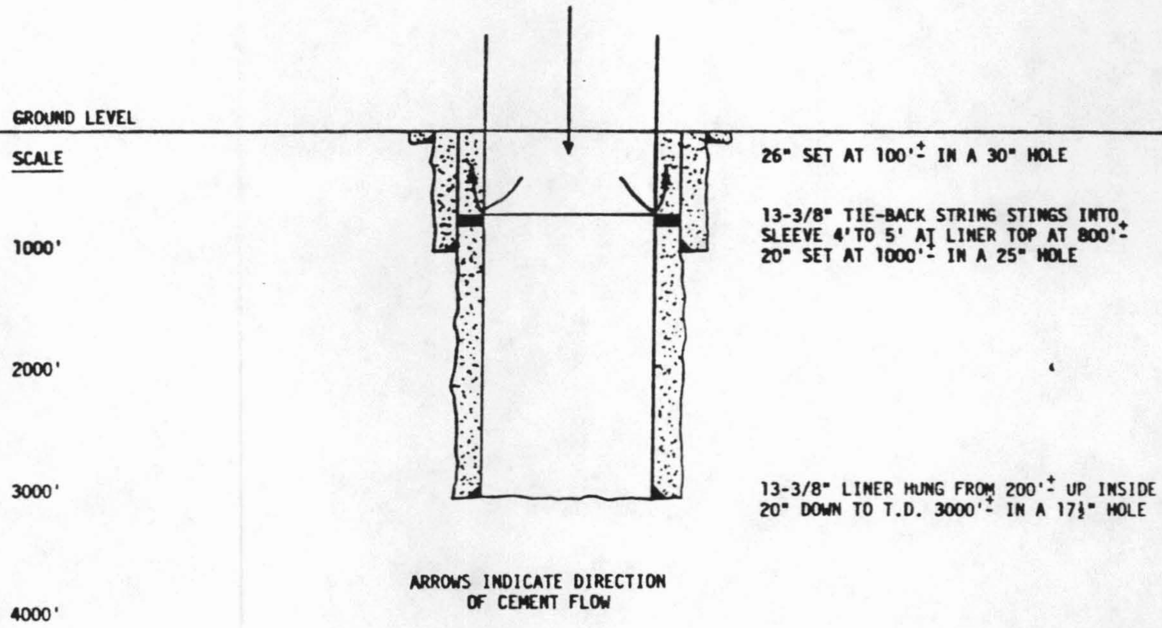
6. Pull out drill pipe. Pull up one joint and displace cement out drill pipe.

7. Pull drill pipe out of hole and wait on cement. If cement had come to surface up the annulus, check after six hours. Refill is necessary.

8. If cement had not come to surface during primary cement job, which is likely the case, run into 26" x 20" annulus with 1" tubing down to upper cement basket. Pump in enough cement to fill 10 linear feet of 26" x 20" annulus, approximately 15.7 cu. ft. Pull up and wait on cement.

9. Go down and feel for cement top. Repeat if necessary and then fill up 26" x 20" annulus to surface with class G cement blended with 40% silica flour and 0.5% CFR-2.

10. Wait on cement six hours and land 20" casing. Cut off 20" and 26" casing. Prepare to install wellhead assemblies.



REVISED	DATE		DRAWN
		TSi ThermaSource Inc. 100 E Street • P.O. Box 1236 • Santa Rosa, California 95402 (707) 523 2960 • Telex 171743 • TWX 510 7446439	FOR: TRUE
			BY: LEC
		13-3/8" TIE-BACK RUNNING AND CEMENTING PROGRAM	DATE: 8/15/82
			SCALE: 1"=1000' Vert
			DRAWING No. 004

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13-3/8" LINER AND TIE-BACK
RUNNING AND CEMENTING PROCEDURE

1. Drill to casing depth.

2. Attempt to fill hole with water and circulate.

3. Rig up loggers and run logs as indicated by geologist.

4. Run in hole with 17½" bit and monel drill collar. Attempt to condition hole for casing. Pull out and run multi-shot directional survey.

5. Pick up 13-3/8" liner. If circulation was never achieved, then a stage collar should be installed at approximately 2000'±. Install cement basket type centralizers in the middle of the bottom two joints and one just below stage collar. Install one cement basket type centralizer 20' below 20" casing shoe and one 20' up inside 20" casing shoe.

6. Run liner in hole and hang same 200' up inside of 20" casing with shoe just off bottom.

7. Attempt to circulate with two times total volume of fresh water. If unsuccessful, then proceed with cement job. See Drawing 003.

8. Pump 200 cu. ft. $CaCl_2$ water and 100 cu. ft. fresh water, followed by 200 cu. ft. Halliburton Flo-Chek, 200 cu. ft. Geo-gel flush, then cement slurries. for Stage 1.

9. Release plugs and repeat preflush for Stage 2 and close cementing ports if necessary.

10. Release hanger and pull out of hole with setting tool. Wait on cement for six hours.

11. Run inhole with 17½" bit and clean out excess cement, if any, from the top of the 13-3/8" liner.

12. Test lap to 750 psi. If unable to get a test, trip to lay down bit, run in open ended. Squeeze lap with class G cement blended with 40% silica flour and 0.5% CFR-2 using pipe rams.

13. Re-squeeze until a squeeze pressure is achieved. Fill hole with water.

14. Drill out excess cement with 17½" bit and retest lap to 750 psi.

15. If successful in testing lap, run in hole with 12¼" bit and 13-3/8" casing scraper to clean out tie-back sleeve.

16. Pick up 13-3/8" tie-back with float collar located 40' above tie-back stinger on bottom. See Drawing 004.

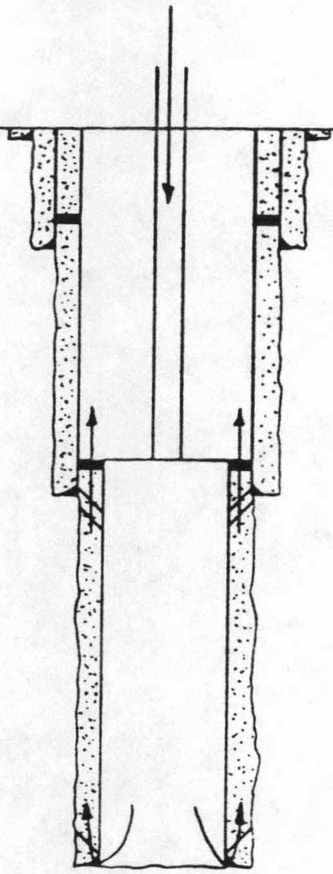
17. Run tie-back string in hole and land same in sleeve at hanger.

18. Circulate around with fresh water, then run cement slurry. Use top plug only.

19. Wait on cement six hours. If after six hours cement is not to surface level in 13-3/8" x 20" annulus, insert 1" tubing and bring it back to surface with cement.

20. Cut off 20" and 13-3/8" casing strings. Install wellhead and blow out preventers as in Drawing 009.

GROUND LEVEL



SCALE

1000'

2000'

3000'

4000'

5000'

6000'

7000'

26" SET AT 100'± IN A 30" HOLE

13-3/8" TIE-BACK STRING SET AT LINER TOP AT 800'±
20" SET AT 1000'± IN A 25" HOLE

9-5/8" LINER HUNG WITH DRILL PIPE AT 2800'±

13-3/8" LINER HUNG FROM 200'± UP INSIDE 20" DOWN TO 3000'± IN A 17½" HOLE.

9-5/8" LINER HUNG FROM 200'± UP INSIDE 13-3/8" DOWN TO T.D. 6000' IN A 12¼" HOLE

ARROWS INDICATE DIRECTION OF CEMENT FLOW

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		TSI ThermaSource Inc. 100 E Street • P.O. Box 1236 • Santa Rosa, California 95402 (707) 523-2960 • Telex 171743 • TWX 510 7446439	FOR: TRUE
			BY: LEC
			DATE 8/15/82
		9-5/8" LINER RUNNING AND CEMENTING PROGRAM	SCALE: 1"=1000' Vert.
			DRAWING No. 005

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CASING, CEMENTING AND BOP PROGRAMS

CASING PROGRAM

SIZE	DEPTH		WELL
9-5/8"	2800' ±	Tie Back	True No.1

INTERVAL	WEIGHT LB/FT	GRADE	JOINT TYPE	CALCULATED SAFETY FACTORS: TOP BURST	BOT. BURST	COLL.	TENSION
0 - 2800'	36	K-55	LT&C or Buttress	2.53	2.35	1.40	4.85

DESIGN CONDITIONS

SURFACE BURST PRESSURE -	1500	PSI	OUTSIDE MUD WT. (COLLAPSE) -	9.0	PPG
INSIDE MUD WEIGHT (BURST) -	13.0	PPG	INSIDE MUD WT. (COLLAPSE) -	0	PPG
OUTSIDE MUD WEIGHT (BURST) -	9.0	PPG	FORM. PRESS. GRAD. AT SHOE (COLLAPSE) -		PPG
FRAC. GRAD. AT SHOE (BURST) -	14.25	PPG	BIAXIAL LOAD: COLL. [X] BURST [X]	BOUYANCY: YES [ ] NO [X]	

CEMENTING PROGRAM

SLURRY DESCRIPTION AND PROPERTIES

SLURRY DESCRIPTION (AND NUMBER)

1140 cu. ft. (704 sacks) class G cement blended with 40% silica flour and 0.5% CFR-2.

DESIRED TOP	EXCESS
Surface	30%

SLURRY VOL. - CU FT / (SLURRY NO.)	1140			
SLURRY YIELD - CUBIC FEET/SACK	1.62			
SLURRY DENSITY - [redacted] #/cu. ft.	116			
THICKENING TIME - DEPTH SCH/HRS, MIN.	2 - 3 hours			
COMPRESSIVE STRENGTH - PSI/HOURS	±2323 psi/8 hours			

RUNNING AND CEMENTING INSTRUCTIONS

SHOE, COLLAR(S) AND JOINT STRENGTHENING

1. Run float collar 40'above tie-back sleeve on bottom.
2. Clean and Bakerloc threads on bottom 4 joints.
3. Tac-weld top and bottom of collars on bottom 2 joints.

CENTRALIZERS AND SCRATCHERS - NUMBER, TYPE AND SPACING

1. Run centralizers in middle of bottom joint and one every other tool joint to surface, except for top 100'.

PREFLUSH, DISPLACEMENT RATE, PLUGS, RECIPROCATION, ETC.

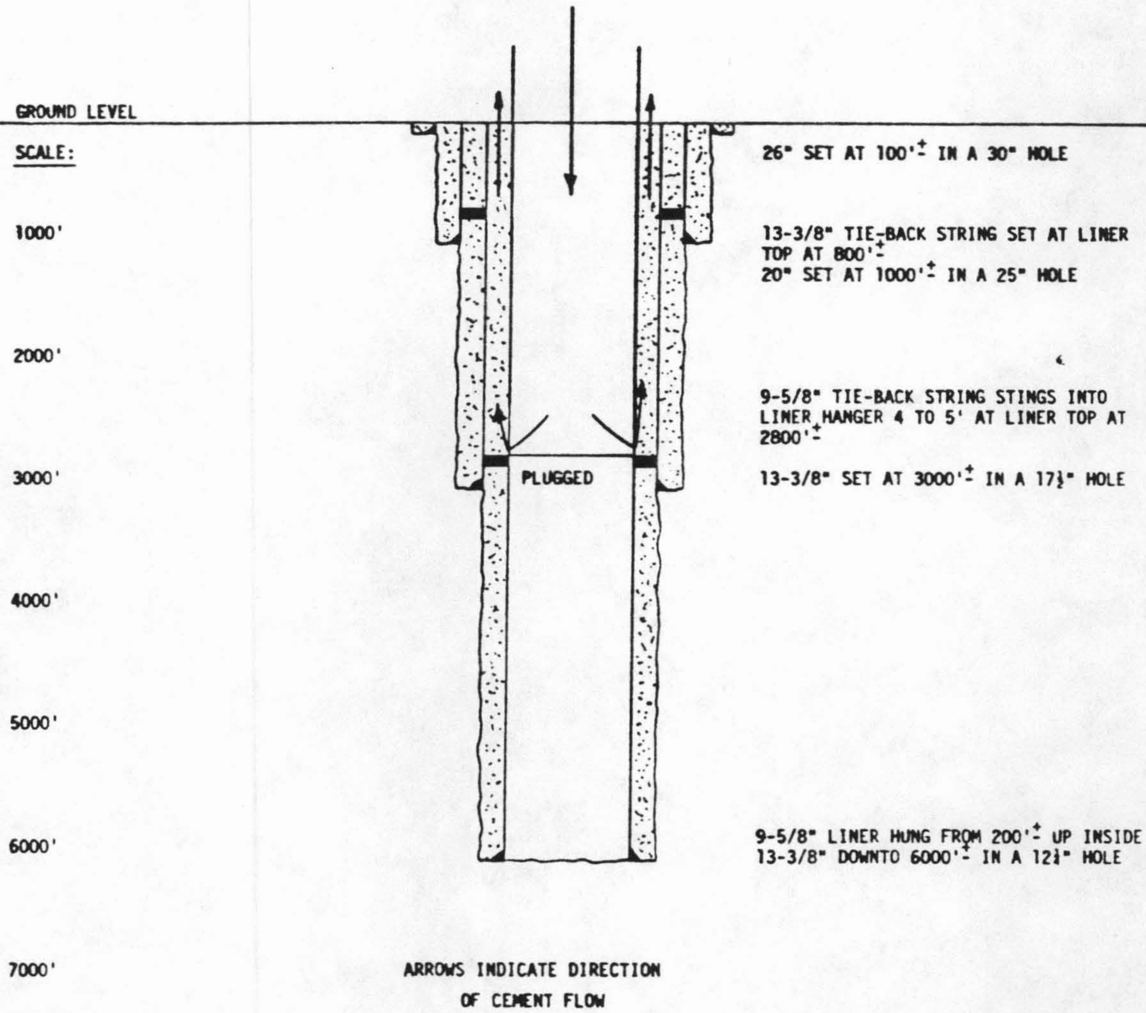
1. Circulate with fresh water.
2. Run top plug only.
3. See attached program for more detail.

PRESSURE TESTING AND LANDING

1. Wait on cement six hours before landing and cutting off 9-5/8" for expansion spool and blow out preventers.

BOP PROGRAM

API STACK ARRANGEMENT CODE	WORKING PRESSURE PSI	MINIMUM BORE INCHES	TYPE	TEST PRESSURES - PSI: RAM TYPE	ANNULAR TYPE	ROTATING HEAD
	1500 psi	8-3/4"	See Drawing 010	1500 psi	1500 psi	1000 psi



REVISED	DATE		DRAWN
		TSi ThermaSource Inc. 100 E Street • P.O. Box 1236 • Santa Rosa, California 95402 (707) 523-2960 • Telex 171743 • TWX 510 7446439	FOR: TRUE
			BY: LFC
			DATE: 8/15/82
		9-5/8" TIE-BACK RUNNING AND CEMENTING PROGRAM	SCALE: 1"=1000' Vert.
			DRAWING No. 006

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CASING, CEMENTING AND BOP PROGRAMS

CASING PROGRAM

SIZE	DEPTH		WELL
9-5/8"	6000'±	Liner	True No. 1

INTERVAL	WEIGHT LB/FT	GRADE	JOINT TYPE	CALCULATED SAFETY FACTORS TOP BURST	BOT. BURST	COLL.	TENSION
2800 - 3300	36	K-55	LT&C or Buttress	2.56	2.54	1.16	3.88
3300 - 4500	40	K-55	LT&C or Buttress	2.82	2.74	1.16	5.19
4500 - 6000	40	N-80	LT&C or Buttress	3.95	3.52	1.10	9.99

DESIGN CONDITIONS

SURFACE BURST PRESSURE -	1500	PSI	OUTSIDE MUD WT. (COLLAPSE) -	9.0	PPG
INSIDE MUD WEIGHT (BURST) -	13.0	PPG	INSIDE MUD WT. (COLLAPSE) -	0	PPG
OUTSIDE MUD WEIGHT (BURST) -	9.0	PPG	FORM. PRESS. GRAD. AT SHOE (COLLAPSE) -		PPG
FRAC. GRAD. AT SHOE (BURST) -	14.25	PPG	BIAXIAL LOAD: COLL. [X] BURST [X]	BOUYANCY: YES [ ] NO [X]	

CEMENTING PROGRAM

SLURRY DESCRIPTION AND PROPERTIES

SLURRY DESCRIPTION (AND NUMBER)

1649 cu. ft. (478 sacks) class G cement blended with 50# per sack of cement of spherelite, 40% silica flour, 5% hydrated lime, 4% gel, 1% CFR-2 and 0.5% Halad-22A. Tailed with 300 cu. ft. (185 sacks) of class G cement blended with 40% silica flour and 0.5% CFR-2

DESIRED TOP: 2800'
EXCESS: 100%

SLURRY VOL. - CU FT / (SLURRY NO.)	1649	300		
SLURRY YIELD - CUBIC FEET/SACK	3.45	1.62		
SLURRY DENSITY - PPG	82	116		
THICKENING TIME - DEPTH SCH/HRS. MIN.	4 hours	2-3 hours		
COMPRESSIVE STRENGTH - PSI/HOURS				

RUNNING AND CEMENTING INSTRUCTIONS

SHOE, COLLAR(S) AND JOINT STRENGTHENING

1. Run float collar 80'± above float shoe.
2. Weld bottom of collars on bottom 4 joints.
3. Clean and Bakerloc threads on bottom 4 joints.
4. Tac-weld top of collars on last 2 joints.

CENTRALIZERS AND SCRATCHERS - NUMBER, TYPE AND SPACING

1. Hang liner 200'± up inside 13-3/8" casing on drill pipe.
2. Run centralizer cement baskets in middle of bottom 2 joints and one 10' up inside 13-3/8" casing and one just below stage collar is a stage is indicated.
3. Run a centralizer every other tool joint to bottom of 13-3/8" casing.

PREFLUSH, DISPLACEMENT RATE, PLUGS, RECIPROCATION, ETC.

1. Attempt to circulate with water.
2. Pump 200 cu. ft. $CaCl_2$ water followed by 100 cu. ft. fresh water, then 200 cu. ft. Halliburton Flo-Chek, then 200 cu. ft. of Geo-gel then cement slurries.
3. See attached program for more detail.

PRESSURE TESTING AND LANDING

1. Wait on cement six hours. Clean out cement from top of 9-5/8" liner. Test lap to 1000 psi. Squeeze lap if necessary. Clean out and retest until a test is obtained.

BOP PROGRAM

API STACK ARRANGEMENT CODE	WORKING PRESSURE PSI	MINIMUM BORE INCHES	TYPE	TEST PRESSURES - PSI RAM TYPE	ANNULAR TYPE	ROTATING HEAD
			NO CHANGE UNTIL TIE-BACK			

TYPE OF OPERATION	SLURRY NO.	CEMENT SLURRY USED	SLURRY YIELD CU. FT./SACK	SLURRY WT. LBS/CU. FT.	WATER REQ. CU. FT./SACK
Conductor	1	API Class G and 3% $CaCl_2$	1.15	118	0.67
Surface	2	API Class G and 50# sacks Spherelite and 40% SSA-1 and 5% hydrated lime and 4% gel and 1% CFR-2 and 0.5% Halad 22-A	3.45	82	1.50
Liner	3	Tail in API Class G cement and 3% $CaCl_2$	1.15	118	.67
Liner	2	API Class G and 50# sacks Spherelite and 40% SSA-1 and 5% hydrated lime and 4% gel and 1% CFR-2 and 0.5% Halad 22-A	3.45	82	1.50
Liner	4	Tail in API Class G and 40% SSA-1 and 0.5% CFR-2	1.62	116	.91
Tie Back	4	API Class G and 40% SSA-1 and 0.5% CFR-2	1.62	116	.91
Whipstock Plug	5	API Class G and 40% SSA-1 and 0.75% CFR-2 retarder	1.49	121	.78
Whipstock Plug	6	API Class G and 15% SSA-1 and 15% SSA-2 and 0.75% CFR-2 and retarder	1.28	126	.63

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CASING, CEMENTING AND BOP PROGRAMS

CASING PROGRAM

SIZE	DEPTH		WELL
7"	T.D.	Blank and Slotted Liner	True No. 1

INTERVAL	WEIGHT LB/FT	GRADE	JOINT TYPE	CALCULATED SAFETY FACTORS: TOP BURST	BOT. BURST	COLL.	TENSION
5800' - 12,000'	29	N-80	LT & C	S L O T	T E D		3.32

DESIGN CONDITIONS

SURFACE BURST PRESSURE – PSI	OUTSIDE MUD WT. (COLLAPSE) – PPG
INSIDE MUD WEIGHT (BURST) – PPG	INSIDE MUD WT. (COLLAPSE) – PPG
OUTSIDE MUD WEIGHT (BURST) – PPG	FORM. PRESS. GRAD. AT SHOE (COLLAPSE) – PPG
FRAC. GRAD. AT SHOE (BURST) – PPG	BIAXIAL LOAD: COLL. ☐ BURST ☐ BOUYANCY: YES ☐ NO ☐

CEMENTING PROGRAM

SLURRY DESCRIPTION AND PROPERTIES

SLURRY DESCRIPTION (AND NUMBER)

NO CEMENT

DESIRED TOP | EXCESS

SLURRY VOL. - CU FT / (SLURRY NO.)				
SLURRY YIELD - CUBIC FEET/SACK				
SLURRY DENSITY - PPG				
THICKENING TIME - DEPTH SCH/HRS, MIN.				
COMPRESSIVE STRENGTH - PSI/HOURS				

RUNNING AND CEMENTING INSTRUCTIONS

SHOE, COLLAR(S) AND JOINT STRENGTHENING

1. Hang liner 200' up inside 9-5/8" casing with drill pipe.
2. No centralizers to be run.
3. Locate slots opposite potentially productive zone.

CENTRALIZERS AND SCRATCHERS - NUMBER, TYPE AND SPACING

no cement.
wash performations if necessary.

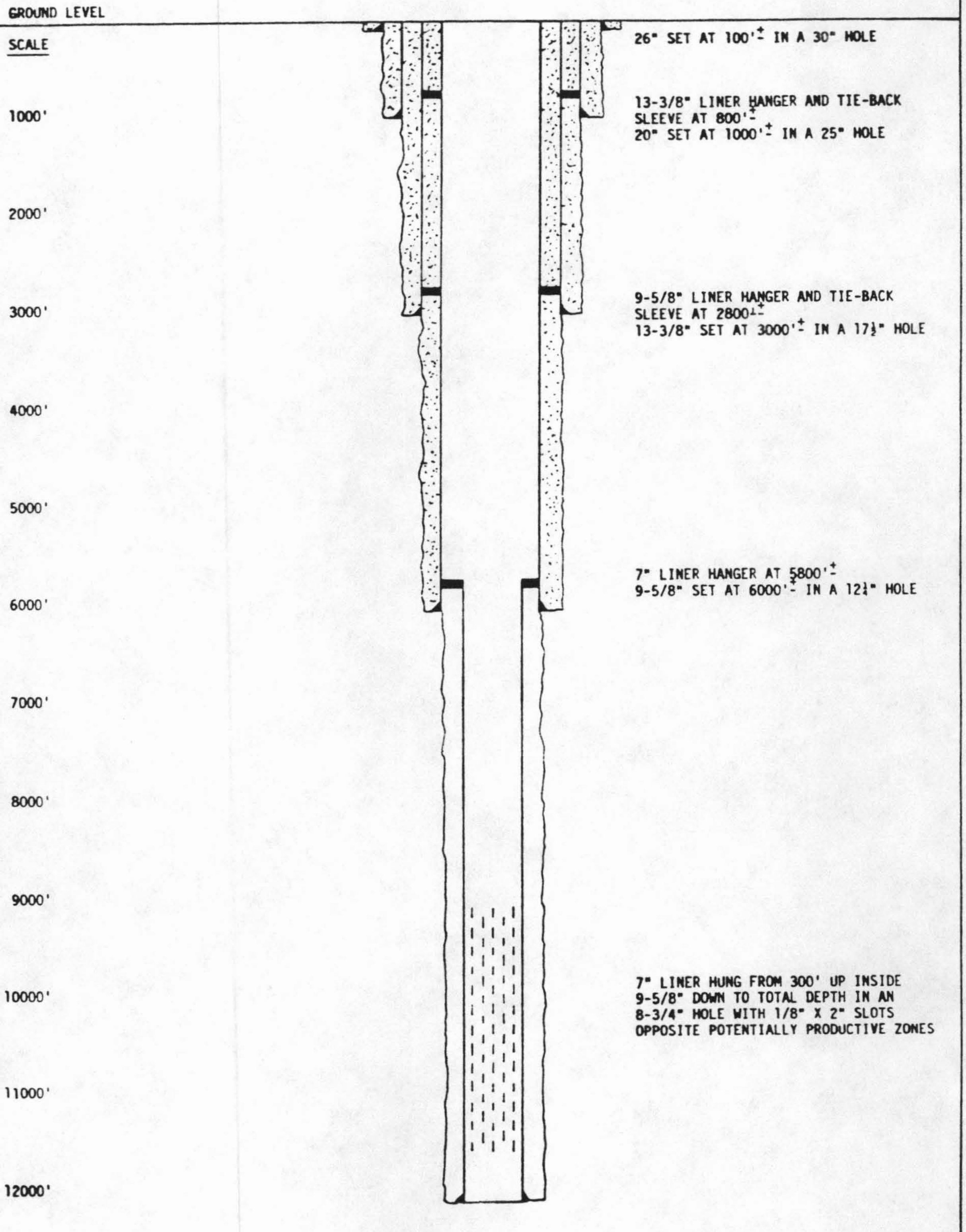
PREFLUSH, DISPLACEMENT RATE, PLUGS, RECIPROCATION, ETC.

no test

PRESSURE TESTING AND LANDING

BOP PROGRAM

API STACK ARRANGEMENT CODE	WORKING PRESSURE PSI	MINIMUM BORE INCHES	TYPE	TEST PRESSURES - PSI: RAM TYPE	ANNULAR TYPE	ROTATING HEAD
			NO CHANGE IN BLOW OUT PREVENTERS			



REVISED	DATE

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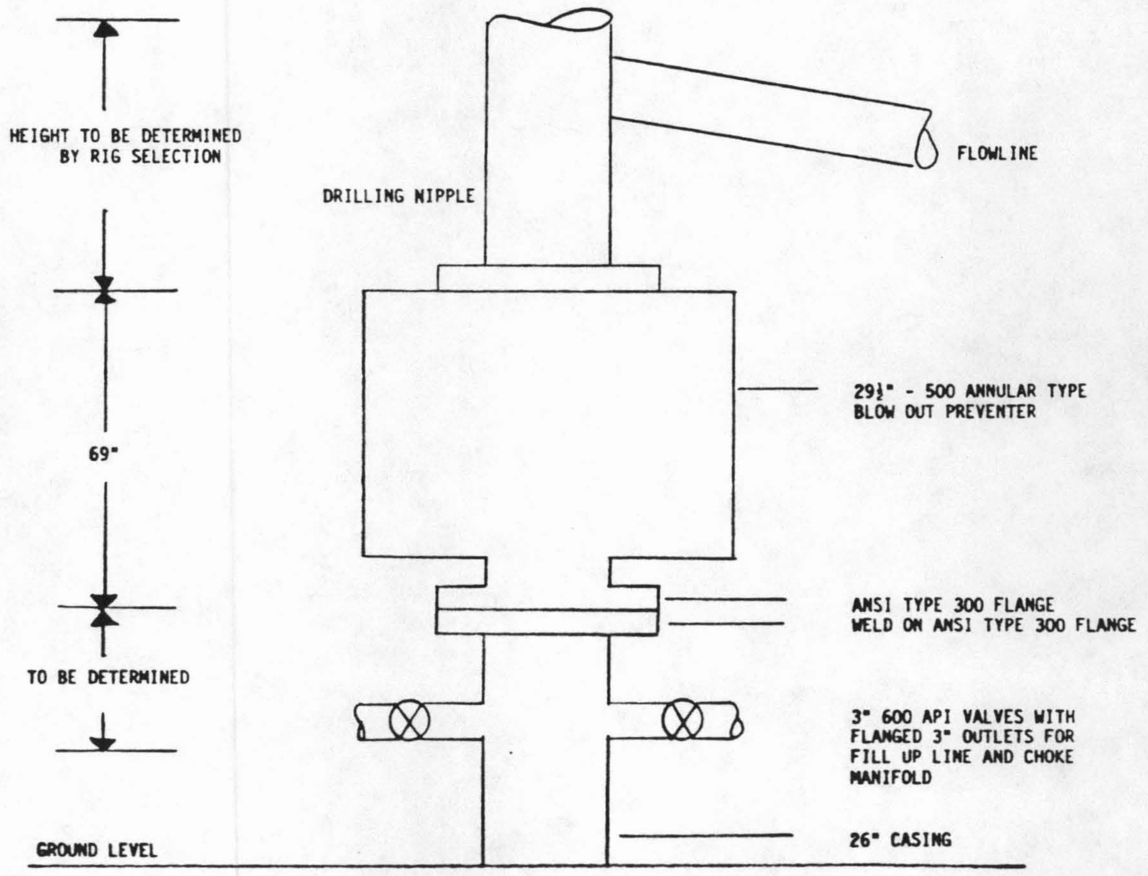
(707) 523-2960 • Telex 171743 • TWX 510 7446439

WELL COMPLETION DIAGRAM
TRUE GEOTHERMAL
HAWAII PROJECT

DRAWN
FOR: TRUE
BY: LEC
DATE: 8/15/82
SCALE: 1"=1000' Vert.
DRAWING No. 001



REVISED	DATE

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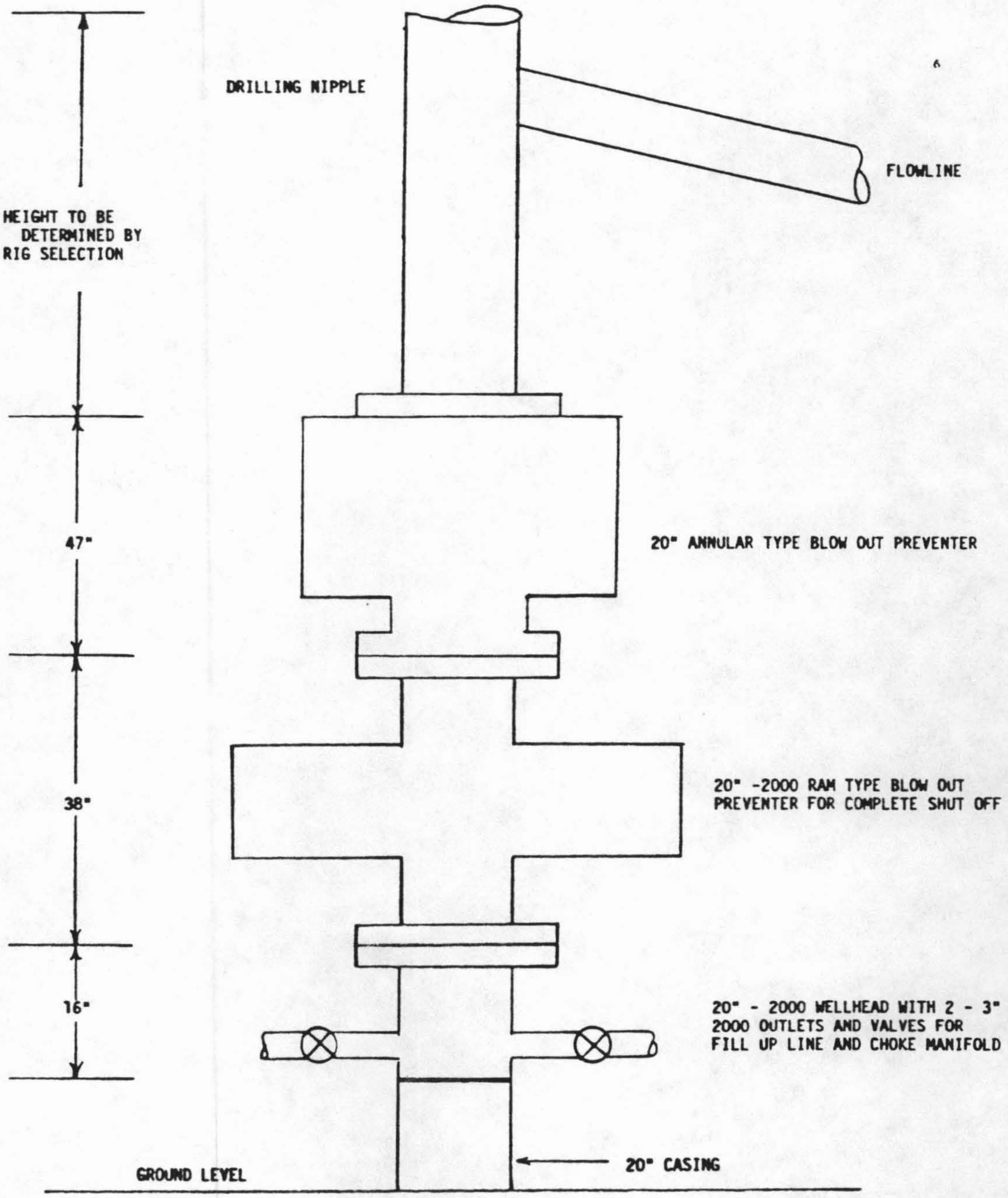
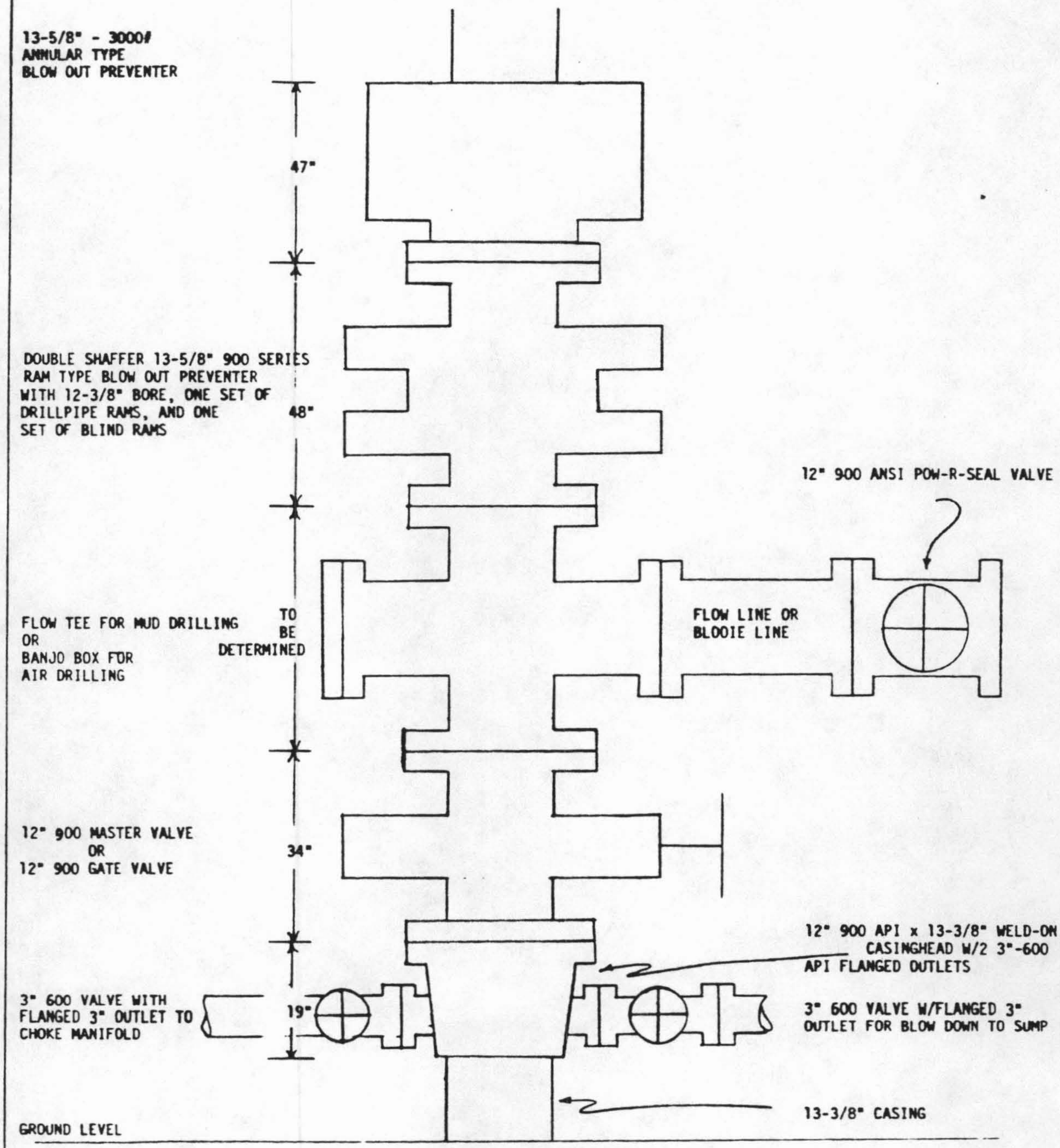
(707) 523-2960 • Telex 171743 • TWX 510 7446439

BLOW OUT PREVENTER STACK FOR 26" CASING
(This stack may be eliminated with State agency approval)

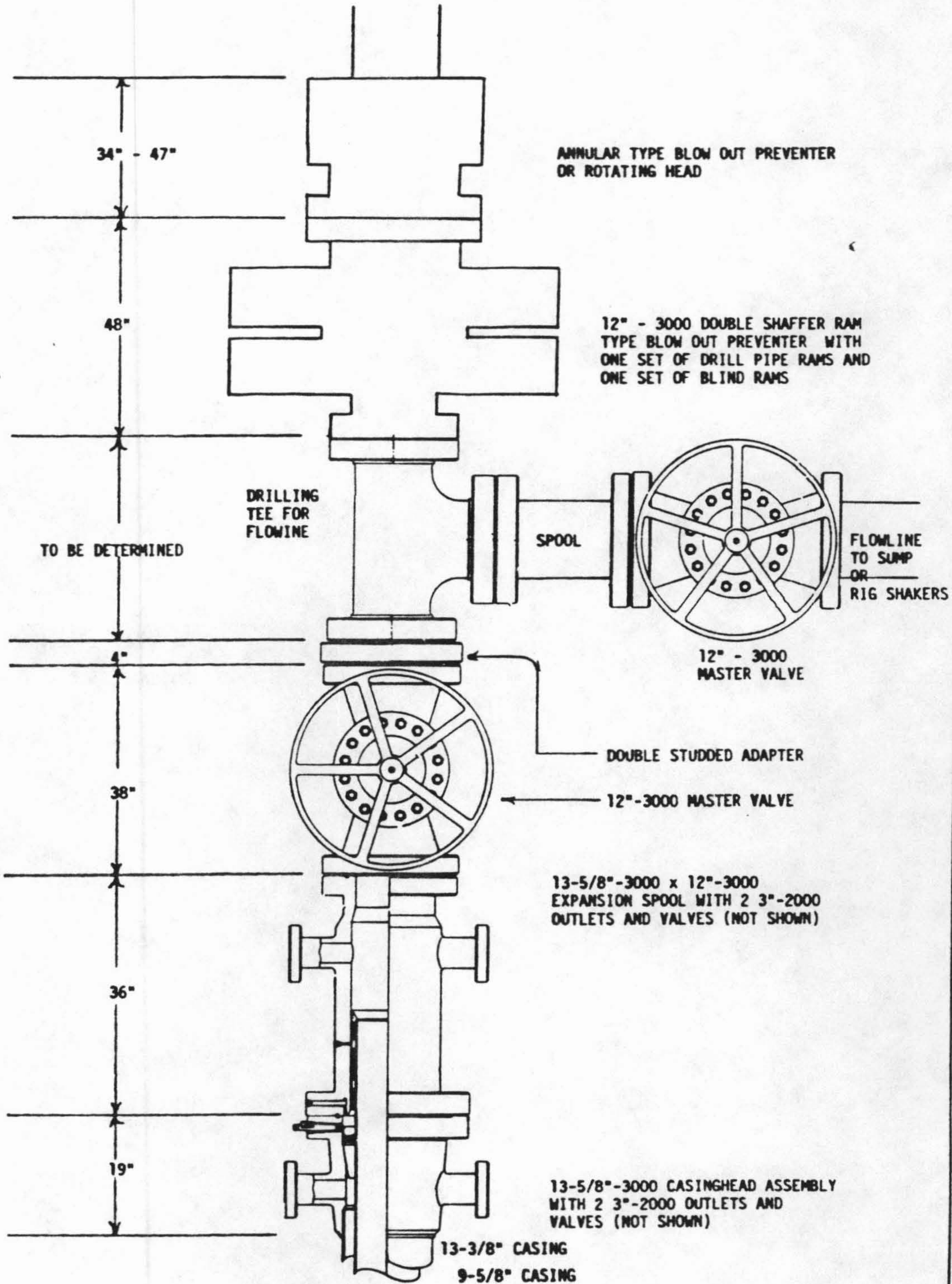
DRAWN
FOR: TRUE
BY: ANG
DATE: 8/16/82
SCALE: NTS
DRAWING No. 007



REVISED	DATE		DRAWN
		TSi ThermaSource Inc. 100 E Street • P.O. Box 1236 • Santa Rosa, California 95402 (707) 523-2960 • Telex 171743 • TWX 510 7446439	FOR: TRUE
			BY: ANG
		BLOW OUT PREVENTER STACK FOR 20" CASING	DATE: 8/17/82
			SCALE: NTS
			DRAWING No. 008



REVISED	DATE		DRAWN
		TSI ThermoSource Inc. 100 E Street • P.O. Box 1236 • Santa Rosa, California 95402 (707) 523-2960 • Telex 171743 • TWX 510 7446439	FOR: TRUE
			BY: ANG
			DATE: 8/17/82
		BLOW OUT PREVENTER STACK FOR 13-3/8" CASING	SCALE: none
			DRAWING No. 009



REVISED	DATE		DRAWN
		TSi ThermaSource Inc. 100 E Street • P.O. Box 1236 • Santa Rosa, California 95402 (707) 523-2960 • Telex 171743 • TWX 510 7446439	FOR: TRUE
			BY: ANG
			DATE: 8/18/82
		BLOW OUT PREVENTER STACK FOR 9-5/8" CASING WITH EXPANSION SPOOL	SCALE: NTS
			DRAWING No. 010

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SPECIAL CONSIDERATIONS

PIPE AND BOP INSPECTION

The initial acceptance of drill pipe should be based on an AAODC-API Class II specification inspection. All subsequent inspections should discard pipe with 30% wear or greater; i.e., use 30% where Class II states 20%.

The drill pipe should include:

1. Electromagnetic inspection of tubes (Sonoscope or Scanalog).
2. Wall thickness and cross sectional area (ultrasonic or gamma ray).
3. End area inspection (electroic or magnetic particle).

All drill collar end areas should be magnetic particle inspected every 14 days, every 9 days in steam or an aerated system.

All BOPs should be inspected for wear by the manufacturer or an authorized agent prior to installation. All BOPs should be tested after installation prior to drilling out cement.

Remind service companies furnishing bottomhole assemblies that their equipment should be magna-fluxed prior to delivery.

AIR EQUIPMENT

Minimum air and pressure requirements are 3000 scfm at 800 psig for rotary drilling. One stand-by unit will be required on the 8-3/4" hole.

Hook-up lines, air meter, and scrubber, misting pump with minimum capacity of 10 gpm, and operating personnel will be furnished by the air contractor. Use Union Oil's Uni Steam corrosion inhibitor while drilling in steam, to be injected into the airline downhole. The mixture for Uni Steam is as follows:

Steam lbs/hr	Injection
None/20,000	5 gal Unisteam - 10/bbl Water
20,000-40,000	10-15 gal Unisteam - 10/bbl Water
40,000-150,000	20-35 gal Unisteam - 10/bbl Water
150,000-plus	40 gal Unisteam - 10/bbl Water

AIR HAMMER INFORMATION

In the event of serious lost circulation or very hard formations, an air hammer may be used. Air hammers are available for various size hole diameters. They require air volumes to operate as follows:

26" Hammer	6000-7000*scfm**@ 160-350 psi
17½" Hammer	3000 scfm @ 160-350 psi
12¼" Hammer	1500 scfm @ 160-400 psi

* This air requirement may be reduced to 2000 scfm by using an accelerator pipe.
** Standard cubic foot (air) per minute

Stabilization is available to maintain a straight hole. Foamer is commonly used to assist hole cleaning when using air hammer.

AUXILIARY EQUIPMENT

1. Six pen drilling recorder with: a) string weight; b) rpm; c) rotary torque; d) rate of penetration; e) pump pressure; f) pump strokes broad.

2. Special rotating head, capable of stripping 12¼" and 8-3/4" BHAs, complete with spare rotating head stripper drive bushing assembly. run cold water continuously on head while in steam.

3. Use square kelly with above.

4. Use tong torque assembly for making up collars.

5. Temperatures should be taken with every directional survey.

6. Install mud loggers as per geologist's instructions.

7. In and out temperatures, both of mud and air, shall be recorded in the Tour Reports every 30 feet prior to rig up of mud loggers. All steam/water entries shall be recorded in the Tour Reports.

8. Periodic tests may be conducted to determine well potential. Drilling will be stopped and the hole evacuated to check for flow.

9. Upon completion, the well will be shut in by closing the lower master valve. The remainder of the BOPE will then be removed.

MASTER VALVE INFORMATION

W-K-M master valve working pressure varies with temperatures of fluids.

900 Series Valve:

No temperature	2160 psi
550° F	1775 psi
600° F	1660 psi
650° F	1550 psi

Outside packing glands should be used above 600° F.

Beveled gear valves should be used.

HYDROGEN SULFIDE MONITORING

Hydrogen sulfide monitoring should be maintained during the drilling of the well. Detectors should be placed on the rig floor, cellar area, and flowline region to detect and announce (with alarms) the presence of hydrogen sulfide. These monitors are typically provided by and maintained daily by the geothermal data loggers. Proper functioning of these monitors is essential in maintaining a safe working environment.

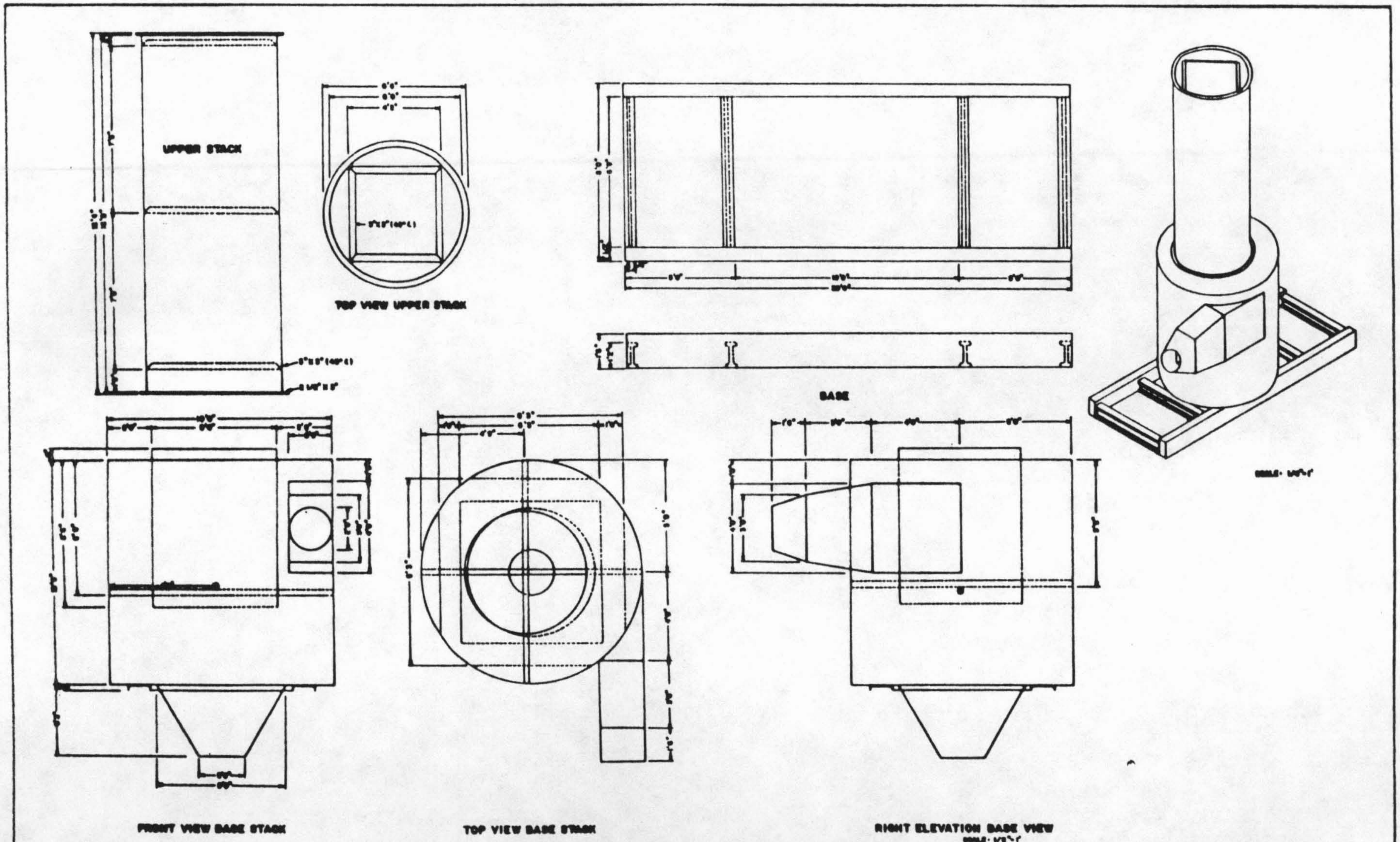
ThermaSource Inc.
P.O. Box 1236 • Santa Rosa, CA 95402

TANGENTIAL MUFFLER

Attached is a drawing of the Tangential Muffler/Separator to be used in True Geothermal-Mid Pacific's geothermal drilling activities. This muffler/separator consists of a large diameter chamber, 10' diameter by 10' tall, with a 6' diameter stack that extends 16' above the 10' chamber. The principle behind this type of device is that the discharge from the well (ambient air circulated downhole and/or steam/water produced from the well) will enter the large diameter chamber tangentially and flow around the chamber, throwing out drilled particles to the side due to centrifugal force in the high velocity air and/or steam exhausted to it. These particles then fall out of the funnel-type structure located at the bottom of the muffler/separator and are channeled to the disposal sump. The air and/or steam must then go down in the chamber to enter the exit stack, the bottom of which sits below the tangential entrance, to be emitted to the atmosphere. The actual blooie line, i.e., the piece of pipe that connects the wellhead and muffler/separator, typically is a piece of 13-3/8" O.D. casing which gradually expands to 36" O.D. and then to a rectangle of a larger cross sectional area than the 36" O.D. pipe. The purpose of this gradual increase is to allow the air and/or steam to expand slowly so as to decrease the noise as much as possible. Water may also be injected, at rates of 60 to 100 gallons/minute, into the muffler/separator as well as the blooie line. The mixing of water with the air/steam exhaust allows some cooling of the steam, which aids in noise reduction. Hydrogen sulfide inhibitors can also be introduced into the exhaust stream upstream of water injection.

Hydrogen sulfide emissions can be abated by the injection of various chemicals into the exhaust stream. Union Oil of California, in conjunction with FMC and Republic Geothermal, Inc., developed a hydrogen peroxide and caustic solution inhibitor that has proven effective in hydrogen sulfide abatement. The hydrogen peroxide and caustic system must be injected in the blooie line as close to the wellhead as possible to give maximum amount of time for the inhibitor to mix with the air/steam discharge.

Continuous monitoring of hydrogen sulfide levels will be made by on-site geothermal data loggers (mud loggers). Metered injections of abatement chemicals to maintain legal emission levels and site safety will also be taken care of by the mud loggers.



MUFFLER AND DUST SEPARATOR

Appendix B

Well Testing

Kahauale'a Geothermal Project

WELL TESTING

KAHAULE'A GEOTHERMAL PROJECT

1. Objectives

Testing a geothermal hot water well should accomplish the following objectives:

A. Evaluate the producing capabilities of the reservoir (aquifer). The well should be produced at or above pre-determined commercial rates to ensure representative samples of the geothermal resource. Surface measurements of mass flow, temperature, and pressure should be monitored. Measuring bottomhole pressures (flowing and shut-in) with downhole recording gauges are desirable but not essential. This data will be used to estimate formation transmissivity, productivity index (PI), and formation damage.

B. Determine properties of the produced fluids. This includes chemical composition, dissolved solids, pH, temperature, enthalpy, and pressure. This data will be helpful in making fluid comparisons between wells to determine aquifer continuity and to anticipate potential long term production problems.

C. Estimate reservoir configuration. Ideally, a well test will provide estimates of long-term producing capability. Unfortunately, the duration of most well tests precludes such estimates unless the reservoir is very small. The well test should be conducted to sample a reasonable drainage area. If any boundaries are located within this area, the pressure buildup should detect it. If the producing formation is a fractured reservoir, then an indication of the well decline rate may be evaluated during a long-term test. Spinner surveys should be considered to determine where the fluids are entering the wellbore.

2. Types of Tests

Several types of well tests are available to satisfy all or part of the test objectives.

A. Rig Test. This is a short term test, usually 24 hours, performed with the drilling rig and equipment in place. Well fluids are sent through a flow line from the well tree assembly to a drilling reserve pit. A choke plate or throttling valve can be installed in the flowline to control flow. Pressure is measured at the end of the flowline (James Lip Pressure) to obtain an estimate of mass flow. Wellhead pressures and temperature should also be measured. A rig test is normally used while drilling after geothermal fluids are encountered to monitor flow rates as a function of depth. It is a quick and simple way to get reservoir flow data for future decision making. The main drawback to this method is that steam quality cannot be estimated.

B. Short Term Test. Short term is defined as less than a month. This procedure involves using a steam/water separator to accurately determine liquid and vapor fractions. The data gathered during this type of test would satisfy all of the objectives listed above. Figure 1 shows a schematic of how the test would be conducted. Fluids would leave the wellhead and go into a separator. The mass flow of each phase would be measured. After the flow is completed, the well should be shut-in and bottomhole pressure measured. If adjacent wells have been drilled, their pressures should be monitored during the test to check for drawdown effects. Additional flow tests may be conducted at different pressures to verify steam quality changes and flow rate variations. In most cases, a short term test is sufficient to describe most of the reservoir parameters of interest.

C. Long Term Test. A long term test is defined as one lasting over one month. Data from a long term test will provide some insight into the time dependency of certain variables such as mass flow, steam quality, and fluid chemistry. A long term test could also quantify well interference effects. It may also detect phase changes that may occur in reservoirs and provide some insight into the size and longevity of the reservoir. Data from a long term test can also be used as a basis for reservoir modeling for long term predictions of well and reservoir performance. Long term tests may even be coordinated with equioment tests of wellhead generators or abatement equipment. The equipment and procedures to conduct a long term test would be the same as a short term test.

D. Drill Stem Test. Drill stem tests are commonly used in oil and gas wells as a means of obtaining well information. Its primary advantage over a simple rig test is that some control is exercised over the zones that are produced. The risk in drill stem testing, particularly in high termperature wells, is packer failure.

3. Recommended Test Procedure for True Geothermal Well No. 1

During drilling and/or immediately after total depth has been reached, a rig test is recommended to determine whether the well is commercial and if further testing is appropriate. If the results of the rig test are positive, then a short term test can be arranged. If the rig tests are negative, new drilling plans to sidetrack or to change locations can be made. Tests should be planned to comply with applicable water, air, and noise regulations. Information obtained during the rig test will be helpful in selecting the proper pressure vessels, piping, and measuring devices needed to perform a rigorous well test.

A long term test may be considered after the short term test has been completed if additional data is required.

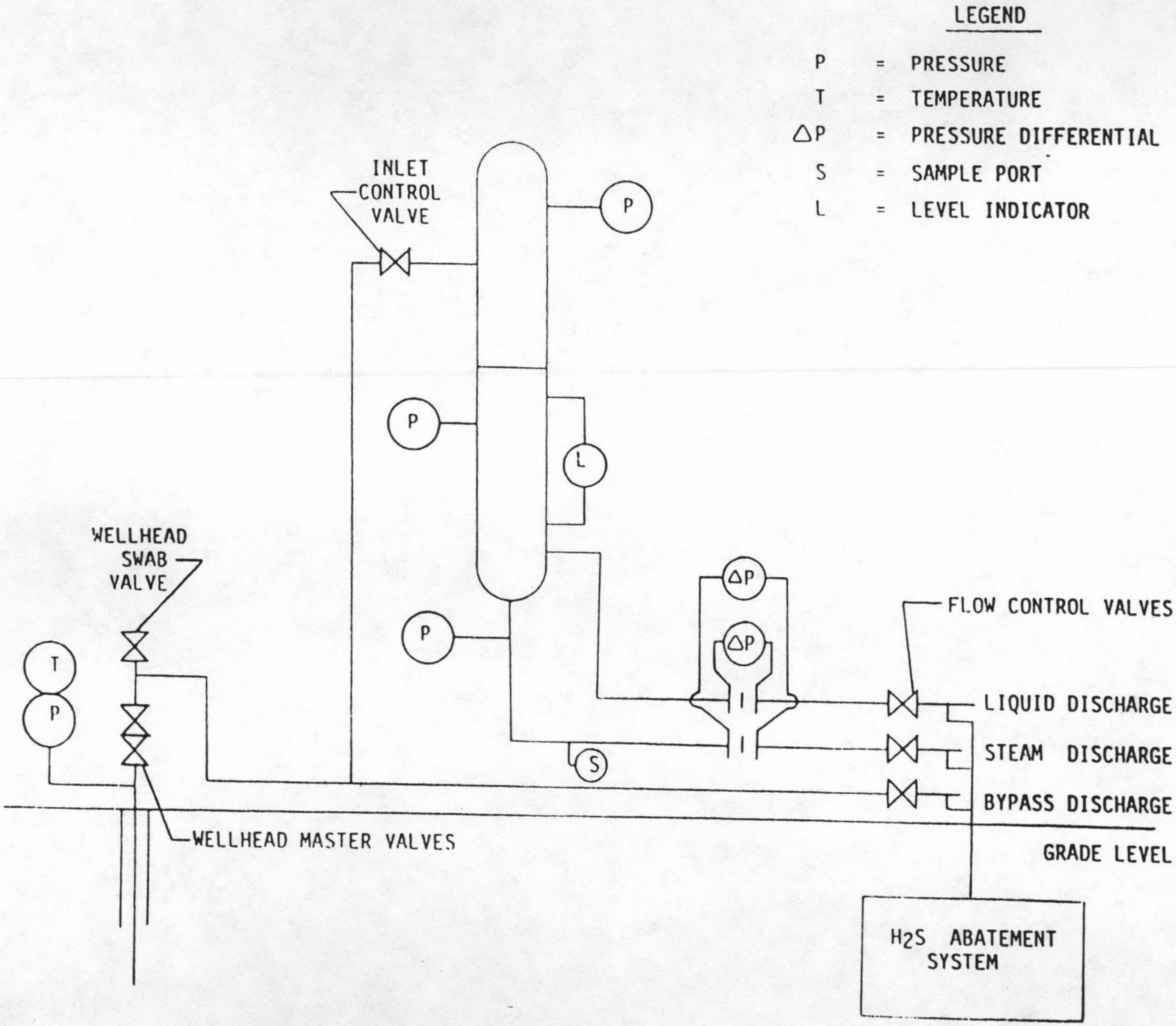


FIGURE 1

REVISED	DATE

SHORT TERM FLOW TEST SYSTEM SCHEMATIC

TSI
ThermoSource Inc.
100 E Street • P.O. Box 1236 • Santa Rosa, California 95402
(707) 523-2960 • Telex 171743 • TWX 510 7446439

DRAWN
FOR:
BY:
DATE:
SCALE: ~
DRAWING No.

Appendix C

Metes and Boonds Description
Of Kahauale'a

DESCRIPTION OF

PORTION OF L. P. 8030, L. C. AW. 8559-B, AP. 14

TO WM. C. LUNALILO

AND PORTION OF GRANT 9275 TO JAMES CAMPBELL ESTATE

ALL that certain piece or parcel of land being a portion of Land Patent 8030, Land Commission Award 8559-B, Apana 14 to William C. Lunalilo and a portion of Grant 9275 to James Campbell Estate.

Situate at Puna, Island of Hawaii, Hawaii.

Beginning at the north corner of this parcel of land and being also the west corner of the Puna Forest Reserve, the coordinates of said point of beginning referred to Government Survey Traiangulation Station "HAKUMA" being 36,435.54 feet north and 48,129.62 feet west and thence running by azimuths measured clockwise from true South:

1.	306°	59'		25,105.30	feet along the Puna Forest Reserve;
2.	296°	00'		8,150.00	feet along the Puna Forest Reserve;
3.	328°	00'		4,100.00	feet along the Puna Forest Reserve;
4.	233°	31'	30"	9,863.3	feet along the Puna Forest Reserve;
5.	310°	00'		1,246.6	feet along Lot 3, Kapaka-Kauka Homesteads;
6.	305°	44'		2,770.6	feet along Government Land;
7.	311°	10'		1,623.0	feet along Lots 1 and 2, Kapau-Kiula Homesteads;
8.	42°	54'		1,588.8	feet along Government Land;
9.	89°	15'		193.8	feet along Government Land;
10.	75°	23'		443.0	feet along Government Land;
11.	311°	51'		2,333.9	feet along Government Land;

12.	58°	41'		594.0	feet along Grant 2372;
13.	19°	30'		186.0	feet along Grant 2372;
14.	10°	20'		990.0	feet along Grant 2372;
15.	317°	21'		716.3	feet along Government Land;
16.	3°	30'		1,430.0	feet along Grant 2723;
17.	330°	23'		1,022.7	feet along Grant 2723;
18.	59°	05'		1,975.0	feet along Lot 1, Kalapana-Kapahua Homesteads;
19.	53°	07'		2,383.8	feet along Lot 2, Kalapana-Kapahua Homesteads;
20.	73°	11'	30"	2,677.7	feet along Government Land;
21.	66°	55'		2,244.0	feet along Grant 3208;
22.	55°	30'	10"	627.60	feet along the remainder of Grant 9275;
23.	68°	12'		2,912.22	feet along the remainder of L. P. 8030, L. C. Aw. 8559-B, Ap. 14 to Wm. C. Lunalilo;
24.	149°	00'		1,911.00	feet along File Plan 1229;
25.	179°	15'		445.00	feet along File Plan 1229;
26.	146°	31'		5,248.36	feet along File Plan 1259;
27.	65°	58'		6,167.92	feet along File Plans 1259 and 1315;
28.	117°	15'		24,536.76	feet along Land Court Application 1374;
29.	32°	30'		8,015.00	feet along Land Court Application 1374;
30.	101°	00'		33,232.70	feet along the remainder of L. P. 8030, L. C. Aw. 8559-B, Ap. 14 to Wm. C. Lunalilo;
31.	152°	10'		6,579.50	feet along Hawaii National Park;
32.	228°	00'		634.00	feet along the remainder of L. P. 8030, L. C. Aw. 8559-B, Ap. 14 to Wm. C. Lunalilo;

33.	252° 45'	18,982.00 feet	along R. P. 7223, L. C. Aw. 8559-B, Ap. 16 to Wm. C. Lunalilo and along Land Court Application 1053;
34.	255° 15'	22,836.00 feet	along Land Court Application 1053 to the point of beginning and containing an area of 26,093.756 acres less Grants 6796, 7439 6189 and 4798 having an area of 179.5 acres and leaving a net area of 25,914.256 acres.

WALTER P. THOMPSON, INC.

By James R. Thompson
Registered Professional
Land Surveyor 3627-S

Honolulu, Hawaii
October 14, 1981

Compiled from all
available data.

Appendix D

Priority List of Evacuation
Of Drilling Equipment

MOVING PRIORITY LIST

PRIORITY ORDER OF MOVEMENT	RIG ITEM	METHOD OF MOVEMENT	COMMENT
1	Generator Unit	Flat bed truck with winch and tail roller	Unit could be disconnected and dragged on flat bed quickly.
2	Fuel and Fuel Tanks	Tanker truck for fuel; Flat bed truck for tank	Fuel would be pumped off onto a transfer tanker truck and the storage tank moved a a low priority item.
3	Air Compressor	Tractor truck without trailer	United are easily disconnected and can be moved with a tractor while generator unit is being moved.
4	Mud Pumps	Flat bed truck with winch and tail roller	Unit disconnects easily after draining mu to sump.
5	Cementing Unit	Tractor truck without trailer	Unit can be maintained disconnected off location to be transported to the site an connected only when needed.
6	Electric Logging Unit	Flat bed truck with winch and tail roller	Unit usually maintained disconnected off location until needed when it is transport to the site and connected for use.
7	Mud Logger's Trailer	Pick-up truck	Unit disconnects quickly and can be moved at any time with pick-up truck.
8	Abatement Equipment	Tractor truck without trailer	Unit maintained disconnected off location while not in use, however, when in use, disconnects easily.
9	Accumulator	Flat bed truck with winch and tail roller	Disconnects quickly for easy movement.

PRIORITY ORDER OF MOVEMENT	RIG ITEM	METHOD OF MOVEMENT	COMMENT
10	Catwalk Racks and Drill Pipe	Forklift and Flat bed truck	Drill pipe in hole or derrick remains on location. Pipe on ground can move quickl with forklift.
11	Parts House/ Change Room	Flat bed truck with winch and tail roller	Only connected to rig with electric wire. Disconnects quickly.
12	Doghouse/Tool-Pushers Trailer and Air Compressor Trailer	Flat bed truck with winch and tail roller/Pick-up truck.	Disconnects quickly for easy movement. Low priority item.
13	Water Tanks	Flat bed truck with winch and tail roller	Water is drained to sump and tank is move as a low priority item.
14	Air Drilling Muffler	Crane and flat bed truck	Moved as low priority item.
15	Mud Tanks	Flat bed truck with winch and tail roller	Mud is drained to sump and tanks moved as low priority item.
16	Sub-structure, Drawworks and Derrick	Crane and flat bed trucks	Low priority items since they require too much time to move. Sub-structures elevat drainworks and derrick base on pedestal approximately 26' above ground level.